

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

Development of a Cellphone Based Monitoring and Management-Support System for Anti-Retroviral Therapy

Prepared by:
Samir Aneil Anand

Dissertation submitted in fulfillment of the requirements for the
Degree of Master of Science in Electrical Engineering

Department of Electrical Engineering
Faculty of Engineering and the Built Environment

October 2005



UNIVERSITY OF CAPE TOWN

Dedication

This research dissertation is dedicated to all the people dealing with the challenges of HIV/Aids and especially to those who are in need of effective treatment in resource limited environments.

University of Cape Town

Declaration

I hereby declare that the following dissertation is my own unaided work, and that apart from the normal guidance of my supervisor, I have received no assistance apart from that stated below. The references refer to research, words and ideas of other people. Neither the substance or any part of this dissertation has been submitted in any form for another degree or diploma at any university or other institute of tertiary education. I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

Author: Samir Aneil Anand

Signature

Signed by candidate

Cape Town

November 2005

Acknowledgements

The author wishes to thank the following people for their contribution towards this research project:

- Prof J Tapson, for the supervision, support and advice throughout this project.
- Dr U Rivett, for the support, motivation and advice during this thesis and for being the driving force behind the Cell-Life Project.
- Mr D de Jager, for being a supportive research colleague and a continuous source of critical questioning and thought.
- The Cell-Life Research Team, for the support and encouragement and for being a great research and development team to work with.
- The NRF (National Research Foundation), for the financial support towards this project.
- Mr K Gajjar, for the contribution to the system architecture and security.
- Usability testing volunteers for their time and feedback.
- Ms S Strassburg for her positive energy and motivational support at all times.
- Most importantly to my family and friends for their encouragement and support throughout this journey.

Synopsis

HIV/Aids has had a major impact on global society since its discovery in 1981. Over the last two decades, HIV treatment research has resulted in the development of antiretroviral (ARV) drug therapy and treatment. However, there are many challenges to ARV Therapy (ART) and these challenges are further extended in the resource limited developing world, where the majority of infections occur. Therefore, ART is regarded as not only a medical challenge, but a logistical, monitoring and management challenge that requires the development and implementation of supporting systems.

The Cell-Life system is a prototype engineering concept that uses locally available ICTs (Information and Communication Technologies), such as GSM (Global System for Mobile) and Internet connectivity to provide monitoring and management-support for ART. This dissertation is an investigation and development of the system in order to create an effective solution for public health sector clinics. The investigation process is based upon a user-centred HCI (Human Computer Interface) model and it is carried out on five components of the system: cell-phone menu applications, SMS data submission and database integration, web applications, servers and user guide and training.

This research has resulted in a progressive advancement and transformation of the prototype concept through the development, testing and pilot site implementation of an updated suite of components with valuable findings from usability testing. This study confirms that locally available ICTs can be developed to empower the resource limited clinic level public health sector to overcome some of the challenges of ART. This essentially contributes to bridging the “digital divide” and providing support in the developing context.

Contents

Dedication	i
Declaration	ii
Acknowledgements	iii
Synopsis	iv
List of Figures	x
List of Tables	xv
Glossary	xvii
1 INTRODUCTION	1
1.1 Subject	1
1.2 Background	2
1.2.1 The Cell-Life Concept	2
1.2.2 The Cell-Life System	3
1.3 Research Objectives	7
1.4 Scope and Limitations	9
1.5 Plan of Development	9
2 LITERATURE REVIEW	11
2.1 Research and Development of the Prototype	11
2.1.1 Pilot Site Implementation	14
2.1.2 Sociological Investigation Findings	15
2.2 Similar Research Projects	16
2.3 HIV/Aids	17

2.3.1	HIV/Aids in South Africa	18
2.3.2	Treatment of HIV	19
2.3.3	The Home-Based Care Model	21
2.4	Information and Communication Technology (ICT)	21
2.4.1	Global System for Mobile (GSM) communication	22
2.4.2	The Internet	26
2.4.3	Open-Source Software (OSS)	26
2.5	HCI Theory and Practice	27
2.5.1	Models of System Development	28
2.5.2	Human Factors Theory	31
2.5.3	Systems Analysis, Design and Testing	35
2.5.4	Theory of Menu Design	36
2.5.5	User Interface Specification	38
2.5.6	Theory and Practice of Web Application Design and Eval- uation	41
3	CELLPHONE MENU APPLICATIONS	44
3.1	User Analysis	44
3.2	Requirements Analysis	45
3.3	Task Analysis	46
3.4	Conceptual Design	47
3.5	Functional Design	50
3.6	Documentation of Implementation	51
3.7	Usability Testing	55
3.7.1	Overview of the WAC Simulator	57
3.7.2	Usability Test Results	58
3.7.3	General Observations and User Feedback	63
3.7.4	Results of Comparative SMS Costs	65
3.7.5	Conclusions	65
4	SMS DATA SUBMISSION AND DATABASE INTEGRATION	66
4.1	Documentation of Current Implementation	66
4.2	Problems and Issues Identified	68
4.3	Quantification of SMS Data Losses and Corrective Measures	70
4.4	Specification and Documentation of SMS Data Submission Mod- ifications	72

4.4.1	WIG Security	75
4.5	Specification and Documentation of Database Modifications	76
4.6	Specification and Design of Test Data and Test Procedures	79
4.7	Test Results	80
5	WEB APPLICATIONS AND OFFLINE DEMONSTRATION SITE	82
5.1	User Analysis	82
5.2	Requirements Analysis	83
5.3	Task Analysis	84
5.4	Design	84
5.4.1	Web User Updates	84
5.4.2	New Functionality	87
5.4.3	Offline Demonstration Web Site	89
5.5	Documentation of Implementation	90
5.5.1	Web User Updates	90
5.5.2	New Functionality	91
5.5.3	Offline Demonstration Web Site	93
5.6	Usability Testing	94
6	SERVERS	99
6.1	Quantification of Problems and Modifications	99
6.1.1	Communication	100
6.1.2	Security	104
6.1.3	Back up System	107
6.2	Client-Side Testing	108
6.2.1	Communication	108
6.2.2	Security	111
6.2.3	Backup System	112
7	USER GUIDE AND TRAINING	113
7.1	User Analysis	113
7.2	Requirements Analysis	113
7.3	Task Analysis	114
7.4	Design and Documentation of Development	114
7.5	Usability Testing	115

8	DISCUSSION	118
8.1	Cellphone Menu Application	118
8.2	SMS Data Submission and Database Integration	119
8.3	Web Applications and Offline Demonstration Site	120
8.4	Servers	121
8.5	User Guides and Training	121
9	CONCLUSIONS AND RECOMMENDATIONS	123
9.1	Conclusions	123
9.2	Recommendations	126
	BIBLIOGRAPHY	128
A	Programming Code	136
A.1	CGI (Perl)	136
A.2	PHP	138
A.3	SQL	146
A.4	HTML	148
A.5	UNIX Shell Scripts	150
A.6	WIG	151
A.6.1	WML Code	151
A.6.2	WML Programming Reference Guide	168
A.7	Firewall Rules	170
A.8	Kannel Settings	171
A.9	Log Files	173
A.10	Java Script	175
A.11	WAC Screen Shot	178
B	Testing Information	180
B.1	Usability Testing	180
B.1.1	Usability Testing Process	180
B.2	System Usability Scale (SUS)	182
B.3	Human Factors Testing (HFT)	183
B.3.1	Test Results	183
B.3.2	Web Applications	187
B.3.3	Sample Patient Home-visit Data	189
B.4	Performance Testing	193

B.4.1	Web Applications Response Times	193
B.4.2	Incoming SMS Transfer Times	195
C	Photographs	196
C.1	Cellphone	196
C.2	Home-based Carer Training	197
C.3	GSM Modem	198
C.4	Server Room	199
D	Additional Information	201
D.1	Cellphone Menu Training Charts	201
D.2	Offline Website Demonstration	204
E	CDRom	207
E.1	CD Insert	207

List of Figures

Figure	Page
1.1 Seven steps of the Cell-Life system cellphone data collection tool [10]	4
1.2 The five main technical components that make up the Cell-Life system	5
1.3 How WIG works [11]	7
2.1 Total estimated global HIV infections by region from the UNAIDS July 2004 Global HIV/Aids Report [59]	18
2.2 Distribution of cellphone users by age in South Africa across all LSMs [16]	24
2.3 HIV prevalence in South Africa by age and sex in 2005 according to the ASSA 2000 Aids Model [1]	24
2.4 Distribution of cellphone users by age in South Africa at LSM 5 [16]	25
2.5 The original software development model, the waterfall method [26]	28
2.6 The star life cycle for user interaction development[24]	29
2.7 The soft system methodology [26]	30
2.8 The prototyping model [52]	30
2.9 The rapid application development model (RAD) [52]	31
2.10 An overview of different menu systems [46]	37

2.11	A transition diagram for a simple menu system [46]	40
2.12	A statechart of a simplified bank transaction system showing group- ing of states [46]	40
3.1	Statechart of the current cellphone menu application	48
3.2	Statechart of the proposed cellphone menu applications	49
3.3	Tree Structure of the Current Cellphone Menu Application	53
3.4	Cyclic Structure of the Proposed Adherence Cellphone Menu Ap- plication	54
3.5	Comparative usability test score results for all 3 application tests	60
3.6	Comparison of task times by group for the new menu (Application A)	61
3.7	Average usability scores for new menu PC test - Group A	61
3.8	Average usability scores for new menu PC test - Group B	62
3.9	Average usability scores for new menu cellphone test - Group A .	62
3.10	Average usability scores for new menu cellphone test - Group B .	63
4.1	The Entity Relationship Database (ERDB) Model Diagram	69
4.2	The Modified Entity Relationship Database (ERDB) Model Dia- gram	78
4.3	Comparison of SMS transfer times relative to quantity load	80
5.1	Average usability scores for all 3 web applications	95
5.2	Average usability scores for all 3 web applications in terms of age group	96
5.3	Average usability scores for all 3 web applications in terms of gender	97
5.4	Average usability scores for all 3 web applications in terms of English first language	97

5.5	Average usability scores for all 3 web applications in terms of training time	98
5.6	Average usability scores for all 3 web applications in terms of task completion time	98
6.1	The five main technical components that make up the Cell-Life system (repeated)	101
6.2	The current coaxial network connection to the database server . .	102
6.3	The new server room network connection to the database server .	103
6.4	Web application server response time from internal LAN - Part 1/2	109
6.5	Web application server response time from internal LAN - Part 2/2	110
6.6	Web application server response time from the Internet - Part 1/2	110
6.7	Web application server response time from the Internet - Part 2/2	111
A.1	WAC Screen Shot - Original Menu	178
A.2	WAC Screen Shot - The Adherence Menu	179
B.1	Participant consent form	181
B.2	Participant background information	181
B.3	The System Usability Scale (SUS) [7]	182
C.1	WIG menu application on a cellphone	196
C.2	Home-based carer training at the Gugulethu Clinic pilot site . . .	197
C.3	Home-based carer training at the Gugulethu Clinic pilot site . . .	197
C.4	The GSM modem	198
C.5	The GSM modem	198
C.6	The server room - network switch	199
C.7	The server room - Cell-Life servers	200

D.1	<i>Monitor Menu</i> Training Chart	202
D.2	<i>Social Menu</i> Training Chart	203
D.3	Cell-Life Website - Home Page	204
D.4	Cell-Life Website - Login Page	205
D.5	Cell-Life Website - Pilot Site Login	205
D.6	Cell-Life Website - Outward SMS <i>smsfinal.htm</i>	206
D.7	Cell-Life Website - SMS Report Totals	206

University of Cape Town

List of Tables

Table	Page
2.1 Summary of the informal prototype development process	12
2.2 Summary of the research projects motivated by the success of the prototype	12
2.3 Summary of HIV prevalence figures for South Africa	19
2.4 Summary of patients on ART in South Africa	20
3.1 Task analysis summary - cellphone menu applications	47
3.2 Cost comparison of cellphone menu applications	65
5.1 Task analysis summary - web applications and offline demonstra- tion site	85
5.2 Summary of the usability test tasks for the 3 web applications . .	94
7.1 Task analysis summary - user guide	114
B.1 Usability testing results summary of current and new cellphone menu applications - Part1/2	184
B.2 Usability testing results summary of current and new cellphone menu applications - Part2/2	184
B.3 Data collection errors from the database for the new monitor ap- plication	185

B.4	Data collection errors from the database for the new adherence application - Part1/2	185
B.5	Data collection errors from the database for the new adherence application - Part2/2	186
B.6	Usability testing results summary of cellphone menu applications charts	187
B.7	Usability testing results summary of current, new and demo web applications - Part1/2	187
B.8	Usability testing results summary of current, new and demo web applications - Part2/2	188
B.9	Overall web application evaluation results	188
B.10	Sample patient home-visit data cards - Part1/4	189
B.11	Sample patient home-visit data cards - Part2/4	190
B.12	Sample patient home-visit data cards - Part3/4	191
B.13	Sample patient home-visit data cards - Part4/4	192
B.14	Simultaneous HTTP request response times from outside the LAN	193
B.15	Simultaneous HTTP request response times from inside the LAN	194
B.16	Table of transfer times of SMSs from cellphone handsets to the database via GSM modem	195

University of Cape Town

Glossary

<i>Acronym</i>	<i>Definition</i>
AIDS:	Acquired Immune Deficiency Syndrome
API:	Application Programming Interface
ARV:	Anti-Retro-Viral
ART:	Anti-Retroviral Treatment/Therapy
BNF:	Backus Normal form
CGI:	Common Gateway Interface
CSS:	Cascading Style Sheets
CVS:	Concurrent Version System
DTD:	Document Type Definition
DTHF:	Desmond Tutu HIV Foundation
FreeBSD	Free Berkley Software Development UNIX Operating
UNIX:	System
GPRS:	General Packet Radio Service
GSM:	Global System for Mobile communication
HAART:	Highly Active Anti-Retroviral Therapy
HCI:	Human Computer Interaction
HIS:	Health Information Systems
HIV:	Human Immunodeficiency Virus
HTML:	Hyper-Text Markup Language
ICT:	Information and Communication Technology
IPFW:	Internet Protocol Fire-Wall
IS:	Information Systems
LBS:	Location Based Services
MMS:	Multimedia Messaging Service
MRC:	Medical Research Council
MTCT:	Mother To Child Transmission

NGO:	Non-Governmental Organisation
OSS:	Open Source Software
OTA:	Over The Air
PDA:	Personal Digital Assistant
PHP:	Hypertext Preprocessor
RAD:	Rapid Application Development
SAT:	SIM Application ToolKit
SSH:	Secure Shell (SSL secure Telnet communication)
SIM:	Subscriber Identity Module
SSL:	Secure Sockets Layer (Encrypted communication)
SMS:	Short Message Service
SQL:	Standard Query Language
STD:	Sexually Transmitted Disease
SUS:	System Usability Scale
TAC:	Treatment Action Campaign
TB:	Tuberculosis
UAN:	User Action Notation
UNAIDS:	Joint United Nations Programme on HIV/AIDS
USAID:	United States Agency for International Development
USSD:	Unstructured Supplementary Service Data
VCT:	Voluntary Counselling and Testing
WAP:	Wireless Application Protocol
WASP:	Wireless Application Service Provider
WHO:	World Health Organisation
WIG:	Wireless Internet Gateway
WML:	Wireless Markup Language
WWW:	World Wide Web

Chapter 1

INTRODUCTION

HIV/Aids has had a significant global impact, especially in the developing world where resource limitations have constrained an effective response. It is estimated that Sub-Saharan Africa has 64.5% of the global HIV infections [59]. In South Africa the government plays an important role in meeting the healthcare requirements of the larger society through the public health sector. However, limitations such as those relating to resources and infrastructure have resulted in the pursuit of innovative solutions to ease the burden and improve the efficacy of existing resources. Information and Communication Technologies (ICTs) are proving to be important components in the development of solutions.

1.1 Subject

The Cell-Life system is an example of where advantage has been taken of wide spread GSM (Global System for Mobile) communication coverage, Internet access and Open-Source Software (OSS) to develop a prototype engineering solution to provide cellphone-based monitoring and management support for Antiretroviral Therapy (ART) at the clinic level of the public health sector.

This thesis is an investigation and a development of a prototype solution in order to support its transformation into an effective working system that addresses the public health sector ART challenges in a developing world context. The investigation and development process is carried out on the main components of

the prototype solution. As the development of the prototype prior to this research was based upon an informal ad hoc methodology, this investigation aims not only to further the prototype development, but also to provide a formal technical documentation of the system based upon relevant academic theory. The focus of the system is to specifically provide monitoring and management-support at the clinic level. Therefore, an HCI (Human Computer Interface)-based, user-centred approach has been taken to meet the “on the ground” functional and usability requirements of the end users.

1.2 Background

Cell-Life is a collaborative research project between the University of Cape Town (UCT) and the Cape Peninsula University of Technology (CPUT - formerly Cape Technikon). Cell-Life’s focus is to investigate and develop information and communication technology (ICT) based applications to support ART at the clinic level within the public health sector of South Africa. The research project’s development has been supported by various sectors and organisations, such as HIV specialist members of the medical sector and the Treatment Action Campaign (TAC). The TAC is a civic organisation campaigning for aspects such as greater access to ART for all South Africans [53]. In 2004, Cell-Life expanded the research and development activities of the system. In mid 2004, in order to support the non-research operations of the organisation such as implementation of researched and developed tools, Cell-Life registered as a Section 21 organisation (not for profit) focusing on the delivery of systems to clinics within the public health sector.

1.2.1 The Cell-Life Concept

The conceptual design and initiation of the research project was developed by U Rivett and J Tapson of UCT and J Davies of CPUT in 2000, as a response to knowledge about the implementation challenges facing the national ART roll-out plan of the South African (SA) government.

1.2.2 The Cell-Life System

In South Africa the common name for a mobile cellular telephone is cellphone, and for the purposes of this report the term cellphone is used. The Cell-Life system is an ICT-based tool providing a means to remotely capture relevant information and data through a cellphone or a mobile phone application. In a pilot site implementation of a cellphone data collection tool, the cellphone provides support through information communication between doctors, treatment locations and patients. It has also been used for ART support through data collection using specifically developed application software. The purpose of the cellphone is to provide a menu-based, real time system to capture treatment-relevant data from the patient such as symptoms and drug adherence. The collected data is recorded on a central database and made accessible to clinic management staff over the Internet to support the ART process. Collected data is then stored in a central database, forming a simple clinic-based patient information system (PIS) of patient records with a remote cellphone data collection tool used in patient aftercare followup.

How It Works

As shown in Figure 1.1, the cyclic flow of data follows seven steps. If a patient is diagnosed as HIV positive, and is at the correct clinical stage to start ART, the patient is counselled and presented with the possible ART options and challenges. Once a patient starts ART, the challenges for the treatment site are the ongoing monitoring and evaluation of the treatment, effective remote follow-up and support, the logistics of drug supply and laboratory blood tests. Additional support is provided to the patient using the home-based care model, described in greater detail in Section 2.3.3.

Technical Background

The system consists of five main technical components that are shown in Figure 1.2. A detailed description of each of these components follows:

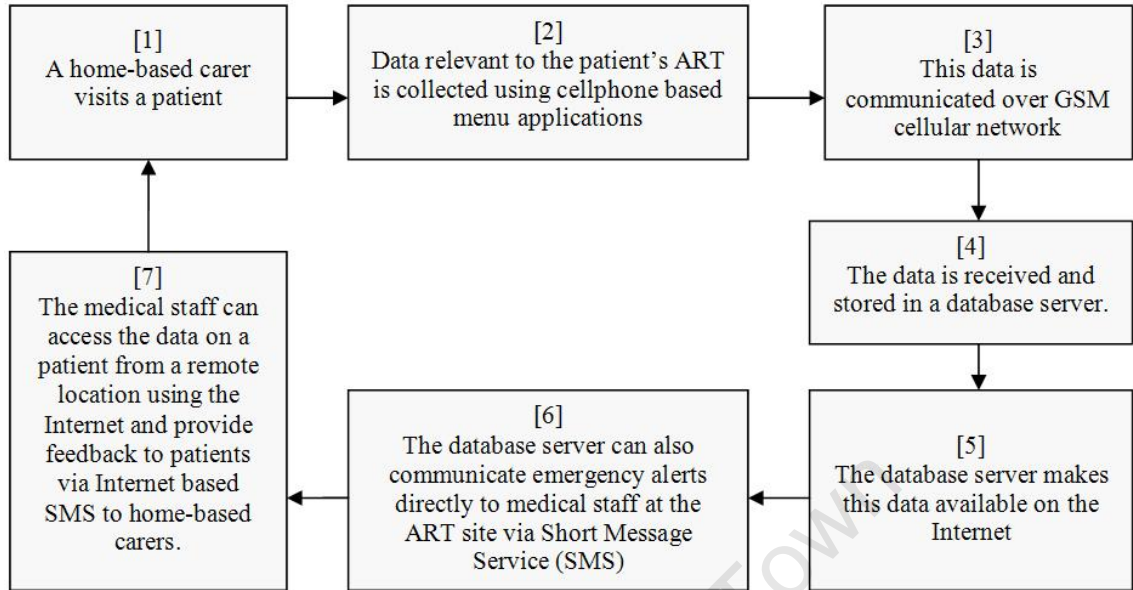


Figure 1.1: Seven steps of the Cell-Life system cellphone data collection tool [10]

1. **Back-end System:** The back-end system includes a database, a web server, and connectivity to the GSM network and to the Internet. The back-end system is implemented on a server and runs a variety of open-source software applications that are essential to the operation of the overall system. The main software applications are:

- FreeBSD (Free Berkeley Software Development) UNIX [18] is the chosen server operating system for following reasons: it is very stable under high loads, easily installed and replicated in the event of future growth, and has community based support with no future intentions of turning commercial.
- Apache web server is used to serve web pages onto the Internet and provide for a Hyper-Text Markup Language (HTML) and World Wide Web (WWW) interface [54].
- A GSM modem is used for all cellphone-based communication. A SIM (Subscriber Identity Module) card is installed in the GSM modem and it provides communication to the server for any GSM based communication via RS232. The software used to monitor and control GSM communications is Kannel [31].
- The database is PostgreSQL and it is a Database Management Sys-

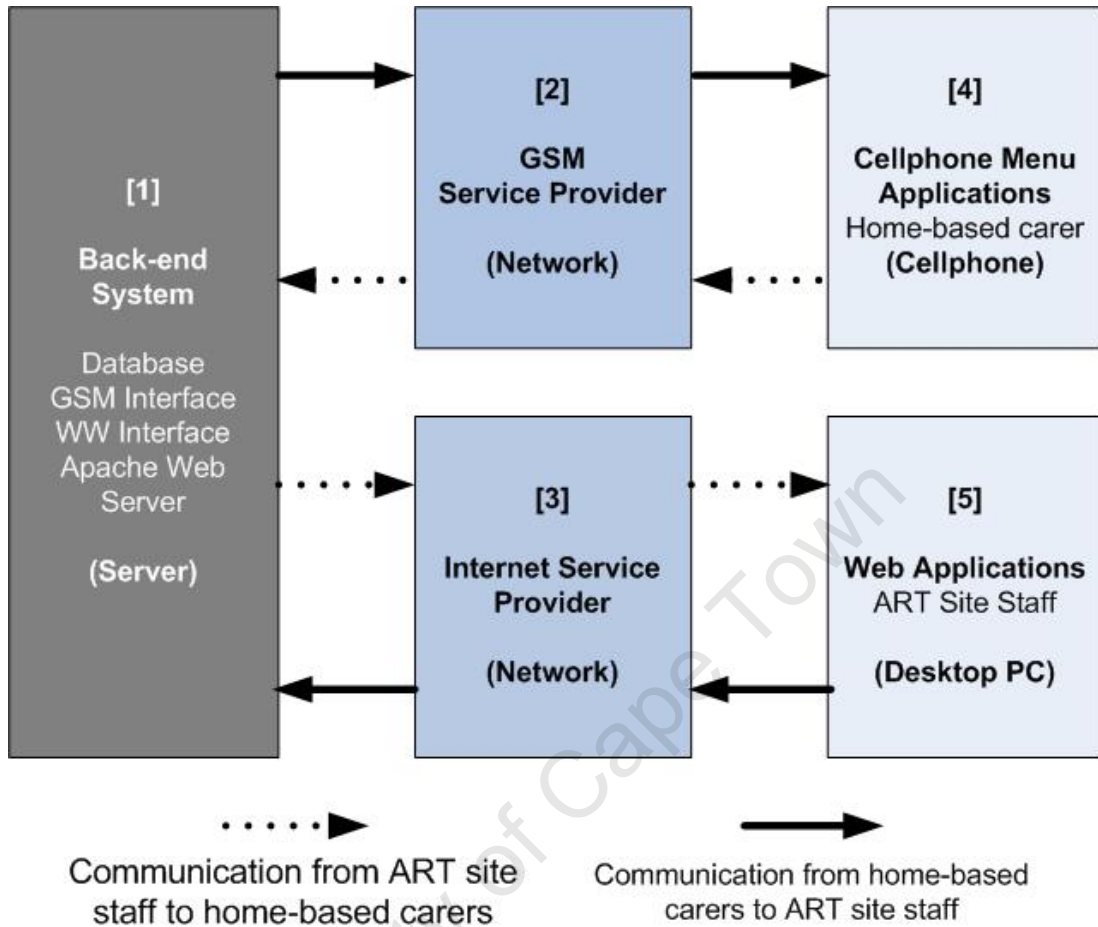


Figure 1.2: The five main technical components that make up the Cell-Life system

tem (DBMS) [42].

- Web-based interfacing needs are met through the use of PHP (Hypertext Preprocessor) and Perl. PHP is a scripting language that can be embedded into HTML for additional functionality such as database queries. Perl can be used for high level functionality such as inserting SMS data into the database.

2. **GSM Network:** The current menu application for data collection is built upon a GSM service called the Wireless Internet Gateway (WIG). WIG enables Internet based services to be accessed via a cellphone as shown in Figure 1.3. All data collected on the cellphone menu application is transmitted via SMS over the GSM network to the network operator's WIG server.

In the current system, the link between the WIG server and the back-end server is not via HTTP(S) but via SMS. At the WIG server, the data from the cellphone is processed and then sent out via an SMS-C(Centre) to a GSM modem attached to the back-end server. Upon receipt of the SMS, Kannel passes the message using Perl scripts to process, extract and store the data within the SMS.

3. **Internet Network:** At present the back-end server is hosted on the university LAN which is connected to the Internet. Therefore web users with Internet access at any remote location can gain access to the stored data.
4. **Cellphone Menu Applications:** One of the older conventional methods for accessing the Internet on a cellphone handset is the Wireless Application Protocol (WAP). A WAP enabled cellphone can make a modem based telephone connection to the Internet via an Internet Service Provider (ISP). Once online, content is served to the handset in a specially designed mobile format called Wireless Markup Language (WML) derived from HTML. As shown in Figure 1.3, the Wireless Internet Gateway (WIG) gives WAP and SIM Application ToolKit (SAT) terminals access to WML-based applications.

However, in a recent development, the 32K SIM card has a built in WML browser and memory allocation. This allows static WML webpages to be programmed into a SIM card and accessed via the built-in browser, and it is called a SAT terminal. These applications can then communicate back to a server via the GSM service provider WIG platform in the form of an SMS.

The menu application is written and programmed in Wireless Markup Language (WML). WML is based upon Wireless Internet Gateway (WIG) communication, which is implemented as a service by the GSM network operator. The WIG menu installation takes place via the cellular network operator through a programming mechanism called Over The Air (OTA). A WIG enabled cellphone such as the Nokia 3310 can then be used for data collection.

5. **Web Applications:** A web user can access data collected by home-based carers through an Internet connection. Through web applications, the user

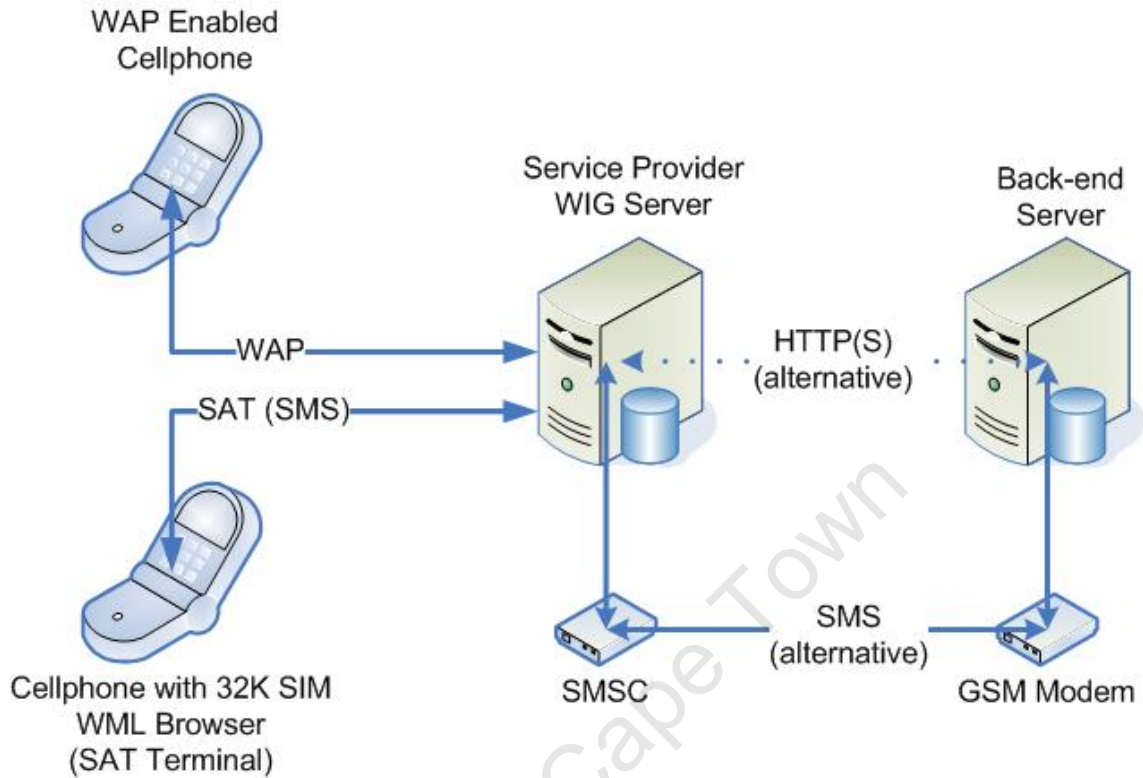


Figure 1.3: How WIG works [11]

can log in to the database using a specific username and password for authentication. Once logged in, the user can view all data displayed in a number of ordered or grouped formats. Typical web users are ART site medical or administration staff.

1.3 Research Objectives

Research Question: Can the prototype engineering concept be transformed into an effective solution to support the public health sector ART challenges in the developing world?

The following objectives of this thesis are carried out on the main components of the prototype system in order to answer the research question:

1. **Cellphone Menu Applications:** Cellphones equipped with menu applications are used in patient aftercare follow-up visits. The first and only

menu version has been piloted for 6 months and important feedback from the menu users and the ART site staff needs to be investigated. New and updated menu(s) are to be specified, designed, developed, implemented and tested. A comparison between the current and the new applications is to be carried out.

2. **SMS Data Submission and Database Integration:** The central data location store of all cellphone collected information is the central database. Menu application amendments will have an effect on the data submission and the database insertion process. These amendments and updates must be carried out and a number of data loss problems investigated in order to develop and implement effective solutions.
3. **Web Applications and Offline Demonstration Site:** ART site staff are able to access the central database over the Internet using specific web applications. At present, the web application system does not have any security implemented and this needs to be investigated and security solutions put forward and implemented in conjunction with improved reporting for ART site staff. There is also a requirement for web-based SMS communication back to cellphone users. In addition, the web applications are required for peri-urban and rural ART site visits where Internet access is limited. They must be in a suitable format for offline demonstration of the web application functionality.
4. **Servers:** A server hosts the database and the web applications and it receives incoming SMS data. At present there are problems with the speed of connectivity for remote users, with the fact that there is no implemented security and that there is no back up system in place. These aspects need to be investigated and solutions developed, implemented and tested.
5. **User Guide and Training:** Lastly, feedback and input is required from cellphone users about the new cellphone menu application(s) in order to develop a formal user guide.

1.4 Scope and Limitations

The scope of this research project was to investigate and document the current state of the Cell-Life prototype and to carry out a formal development of the prototype based upon relevant academic theory. The research was limited to the technical components of the prototype, with user interaction taking place only at the user and requirements analysis and usability testing stages. The intention is to develop the system within the role of monitoring and management support of ART at the clinic level of the public health sector.

1.5 Plan of Development

The thesis consists of nine chapters summarised as follows:

1. **Chapter 1:** An introduction to the thesis is given, including the subject, background, research objectives, scope and limitations and plan of development.
2. **Chapter 2:** The literature review includes an investigation into past research and development of the prototype, followed by an evaluation of similar research projects. As the prototype operates in the specific context of HIV/Aids, an investigation into the current state of the disease and treatment challenges in the public health sector is carried out. Specific information and communication technologies (ICTs) are used in the prototype and a background to the current state of ICT is given. Lastly, the development of the system is based upon user specific needs, and the relevant HCI (Human Computer Interface) theory used in the development process is reviewed.
3. **Chapters 3 to 7:** Each chapter is a documentation of the formal systems development process carried out on the components of the system based upon the research objectives described in Section 1.3. The areas covered in each chapter include:
 - Cellphone menu application
 - SMS data submission and database integration

- Web applications and offline demonstration site
 - Servers
 - User guide and training
4. **Chapter 8:** This chapter includes a summary and a discussion of the testing results and the findings from the previous five chapters.
 5. **Chapter 9:** The report ends with conclusions of the research and recommendations for further research.

University of Cape Town

Chapter 2

LITERATURE REVIEW

The literature review covers a number of topics associated with the prototype system. A review of the informal and formal research and development of the prototype is covered. An investigation was carried out to ascertain if similar projects existed with respect to the specific type of application and technology usage. This is followed by a short review of the state and availability of local ICTs. The chapter ends with a review of the relevant HCI theory used in the system development process.

2.1 Research and Development of the Prototype

The original concept of harnessing the potential of ICTs to develop supporting solutions to the ART challenges in South Africa was conceived by U Rivett of UCT in 2000. Over 2000 and into 2001, U Rivett consulted with a number of experts in the HIV and ICT fields, including L G Bekker of the Desmond Tutu HIV Foundation (DTHF). The concept as described in Section 1.2.1 was not envisioned upfront but it evolved over time with support from J Tapson (UCT) and J Davies (CPUT).

Table 2.1 is a summary of the informal development process of the prototype. In 2001, U Rivett and J Davies carried out the initial user and requirements analysis followed by the technical development of the system by three volunteer

<i>Period</i>	<i>Development</i>	<i>Person(s)</i>
2000	Original Concept	U Rivett
2001	Conceptual Design	U Rivett, J Tapson, J Davies
2001-2002	Prototype Devevelopment	J Ainslie, A Sachs, B Babs
2002	Pilot Site Implementation	U Rivett, L G Bekker
2002	Basic Technical Documentation	W Euvarad

Table 2.1: Summary of the informal prototype development process

developers: J Ainslie, A Sachs and B Babs. The developers were from industry and they built the first prototype of the Cell-Life system based upon the conceptual design and analysis described above. Once complete, the Desmond Tutu HIV Foundation (DTHF) agreed to pilot the system as part of their existing ART research project and this is described in greater detail later in this section.

As the technical development of the system had been carried out by industry volunteers, there was no formal documentation of the system and a basic descriptive document of the technical aspects of the system was produced by W Euvarad. The development of the prototype was a first-round evaluation of the original concept and it was not based upon a formal research process or methodology.

<i>Period</i>	<i>Research Topic</i>	<i>Person</i>	<i>Degree</i>
2002-2003	Cell-Life: A needs assessment study for an HIV/Aids management tool	V A Nxumalo	MSc(Eng) Civil UCT
2002-2003	The use of spatial information systems in the management of HIV/Aids: A study of Gugulethu	K Busgeeth	MSc(Eng) Civil UCT
2002-2004	Development of a Cellphone Based Monitoring and Management-Support System for Anti-Retroviral Therapy	S A Anand	MSc(Eng) Elec UCT
2003	Investigation of mobile phone technologies for the Cell-Life project	M Parker	BTech(Eng) Elec CPUT

Table 2.2: Summary of the research projects motivated by the success of the prototype

The positive uptake of the technology at the ground level by home-based carers and ART site staff resulted in the motivation for formal research. The initiation of four research projects over 2002 and 2003, is summarised in Table 2.2.

The following is a summary of the findings from these research projects:

V A Nxumalo 2002-2003

V Nxumalo investigated the readiness of the health regions within the Western Cape with respect to the implementation of the Cell-Life system. The research presented an assessment of the technology requirements of the Cell-Life system to support ART as well as GIS (Geographical Information System). An assessment of the Gugulethu pilot site located in a resource-constrained urban setting was carried out. Further research was carried out to assess the Cell-Life system requirements across the Western Cape province. The findings showed that the system could be implemented in health regions across the Western Cape but that each site implementation would require an individual in-depth assessment study [39].

K Busgeeth 2002-2003

K Busgeeth investigated the design and development of an HIV/Aids database, embedded in a Spatial Information Management System (SIMS) using MS Access. The original database developed in the prototype was used as the base. The database was evaluated and after carrying out user analysis and modelling, a new HIV/Aids database was proposed as well as a SIMS. The research showed that an HIV/Aids database could be successfully implemented as a SIMS supporting the planning of healthcare services. It was noted however, that such an implementation would be a long-term undertaking, and not a solution to the HIV/Aids pandemic but rather a vehicle for facilitating public health planning and contributing to community-based decision-making and policy development [8].

S A Anand 2002-2004

The research project described in this document by S Anand was initiated in September 2002 and research and development work was carried out until February 2004.

M Parker 2003

M Parker investigated the potential use of upcoming cellphone technologies such as USSD (Unstructured Supplementary Service Data), Java CLDC (Connected Limited Device Configuration) and Java MIDP (Mobile Information Device Profile) that have the potential to solve the limitations of WIG applications. The findings showed that of the three technologies, the rating of preference based upon a weighting of the comparative effectiveness, efficiency, user friendliness, cost, accessibility and reliability resulted in USSD being the first choice, followed by CLDC and then MIDP. However, the handset and communication costs of the three technologies at the time (2003) were significantly more expensive than WIG although this is expected to change in the future [40].

2.1.1 Pilot Site Implementation

The Desmond Tutu HIV/Aids Centre based at the Department of Infectious Diseases in the Faculty of Medicine at UCT is the research organisation that is currently piloting the system. The foundation conducts ART research based upon the home-based care model. At the onset of the pilot project in early 2002, approximately 75 patients were being supported by five home-based carers using the first cellphone menu application. The ART programme was called the Sizophile and it was based in Gugulethu [35]. Gugulethu, meaning “Our Pride” in the local Xhosa language, is based twenty kilometres from the Cape Town city centre and it is a community of previously disadvantaged South Africans. The township was established by the South African Government in 1948. Gugulethu is arguably one of the oldest and fastest developing black townships in South Africa and it is home to approximately 325,000 people [8].

2.1.2 Sociological Investigation Findings

In early 2003 an independent investigation of the system was carried out by D Skinner [48] of the Human Science Research Council (HSRC) of South Africa. Some of the findings are subjective and not directly relevant to the technical research aspects of this report, but they do give valuable insight into the users' perspectives on the system. The methodology of the study focused on the qualitative aspects of evaluation. The evaluation took place in two phases, with six months in between. Counsellors were individually interviewed after giving written and verbal consent to the research process. The following is a summary of the findings from the study:

Cellphone Users:

The report showed that according to the home-based carers, the use of cellphones had a direct positive impact on the recording and collection of data, due to the increased efficiency in data collection. The realtime data collection process increased the level of confidentiality according to users, who felt that stigma in the local community was a concern. Patients appreciated the improved response to emergency services requested via the cellphone, and cellphone voice communication also provided a back up communication link in the event of any emergencies. The newer Nokia cellphones with larger display screens and a silent vibrate alert were regarded as an improvement in comparison to the original Siemens A35 cellphones with regard to ease of data collection. One of the subjective findings was the increased level of confidence and a sense of empowerment which came through the allocation and use of the cellphone. The only fears linked to the cellphones were those associated with crime, such as mugging due to the increased risk of carrying a cellphone, and also the possibility of submitting incorrect data by mistake.

Web Application User:

An ART site home-based carer coordinator with access to the collected data, has the ability to provide quicker, more effective support when required and this has had a positive impact on the home-based carer team, owing to increased follow up and accountability for home-based carers by the site coordinator.

2.2 Similar Research Projects

In order to further understand the application of ICTs to support the health sector as carried out by the Cell-Life system, a search of similar research projects or systems was conducted. There are many health information systems available that have been adapted to the needs of ART. There are also a number of cellphone-based solutions targeting the commercial industries, such as banking and marketing [20]. Insight into such projects is important with respect to understanding the state of development of similar or complimentary systems and how relevant aspects could contribute to this research project.

Of the many ICT-based research projects investigated, it was found that many are based upon reminder systems, and some have attempted to use alternative mobile devices such as PDAs and pagers. This differs from the Cell-Life system which is designed to collect information from patients rather than push information to them. A few examples of relevant ICT based systems are summarised below:

- A similar research project to the Cell-Life system published in the *Engineering in Medicine and Biology Society, 2001: Proceedings of the 23rd Annual International Conference of the IEEE* is titled “A patient monitoring tool for an HIV/Aids integral care model” [9]. An Internet-based care model is implemented allowing patients to carryout self-monitoring. Evaluation results show a positive user acceptance and give feedback to improve the validity of the tool and the procedures that enable a web-based model for HIV/AIDS patient care.
- In the journal *Aids Care* of December 2003, titled “Use of an on-line pager system to increase adherence to antiretroviral medications” [44]. Researchers tested the feasibility, utility, and efficacy of a customisable reminder system using pagers, which were programmed using web-based technology, to increase and maintain proper adherence in patients with pre-existing adherence problems. While the provision of a reminder system helped improve adherence, it is likely that more intensive interventions are required for patients with pre-existing problems. This research demonstrates the challenges that exist with respect to using a reminder system to improve adherence.

- The *International Journal of STD & Aids* of May 2001, titled “Impact of an alarm device on medication compliance in women in Mombasa, Kenya” [19] reports on a randomised controlled clinical trial that was conducted to determine the efficacy and acceptability of an alarm device for improving medication compliance amongst women in resource poor countries.
- The SATELLIFE PDA Project’s [5] goal is to demonstrate the viability of handheld computers or PDAs (Personal Digital Assistants) in addressing the digital divide among health professionals working in Africa.

The following are two relevant commercial applications based upon similar technology and similar application respectively:

- Fundamo, a Cape Town based company, is a leading South African banking and mobile commerce software company specialising in transactional banking and mobile payment solutions. Fundamo develops commercial applications for the business sector in areas such as banking [20]. Conceptually, the underlying technical components are very similar to those of Cell-Life. This has resulted in Fundamo providing valuable pro-bono technical development advice and support to the Cell-Life project.
- A Cape Town based project run by Dr David Green and the Western Cape Health Department is using ICT to support TB compliance. The system called Simpill is using SMS to alert tuberculosis (TB) patients to take their medication [6].

2.3 HIV/Aids

The Cell-Life system is specifically designed to support the public sector ART challenge. Therefore the context of HIV/Aids needs to be addressed, and this section provides a base level insight and overview of HIV/Aids.

Since the discovery of the Acquired Immune Deficiency Syndrome (AIDS) and the Human Immunodeficiency Virus (HIV) in the early 1980s, UNAIDS [59] estimate that more than 20 million deaths have occurred in just over 20 years. From this information a rough calculation averaging the number of deaths over

20 years results in estimate average of just over 2700 deaths per day. The current global estimate for HIV infections as of 2004 was 38 million [59].

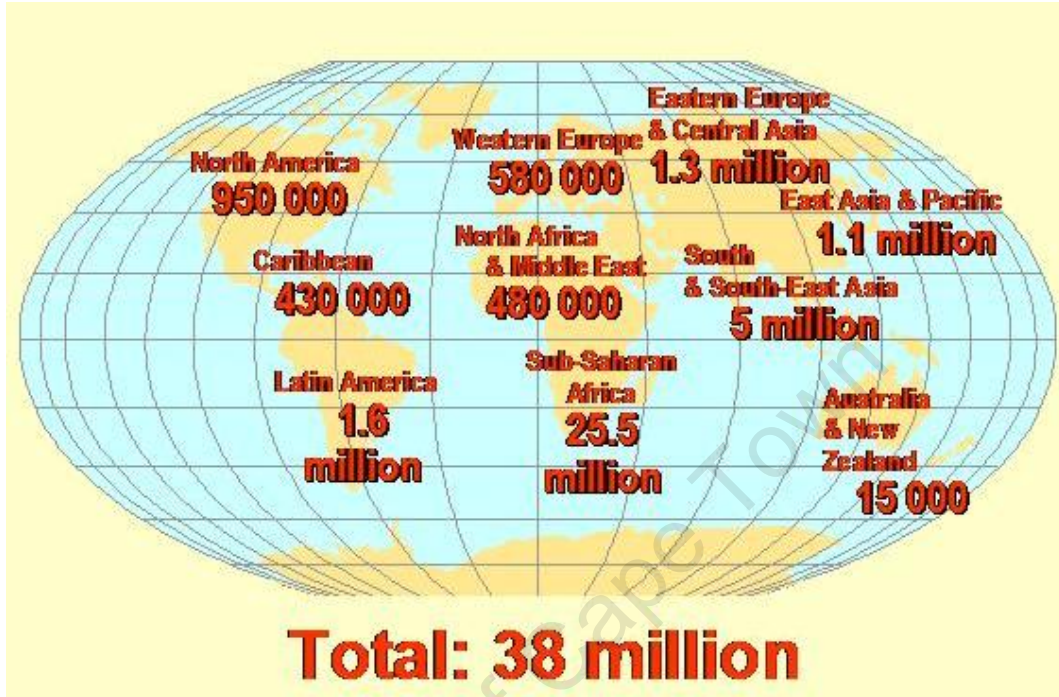


Figure 2.1: Total estimated global HIV infections by region from the UNAIDS July 2004 Global HIV/Aids Report [59]

The pandemic has had a massive impact on the world. Aids has negative impacts on economic growth and development, exacting a devastating toll on individuals and families. In the hardest-hit countries it is erasing decades of health, economic and social progress, reducing life expectancy by years, deepening poverty, and contributing to and exacerbating food shortages [59]. However, the brunt of these effects have taken place in developing countries, particularly in Sub-Saharan Africa, which is faced with 64.5% of the global estimate of HIV infections.

2.3.1 HIV/Aids in South Africa

South Africa is faced with one of the highest HIV/Aids prevalence rates in the world, with estimates of infection ranging between 18.5%-24.9% of the adult population. This indicates that South Africa has the largest number of individuals living with the virus in a single country [59].

However, over the last few years there have been varying discrepancies in the estimates from organisations such as UNAIDS, the Actuarial Society of South Africa (ASSA) [2] and Statistics South Africa (STATSSA) [43] as summarised in Table 2.3. Such discrepancies exist due to the difficulties of data collection at the ground level and the differences in assumptions and methods of the estimation employed by the models.

<i>Organisation</i>	<i>HIV Prevalence</i>	<i>SA Population</i>	<i>HIV as % of Population</i>
UNAIDS	5.3 million	44.8 million	11.8%
ASSA	3.8 million	44.8 million	8.5%
STATSA	3.7 million	44.8 million	8.3%

Table 2.3: Summary of HIV prevalence figures for South Africa

UNAIDS uses a limited number of resources and simplified generic models to estimate, assess and evaluate all the countries in the world. ASSA and STATS SA are South African organisations who better understand the local context and they can therefore be relied on to provide more accurate estimates.

In addition to these challenges, the public health sector in South Africa is overburdened and overwhelmed. Of the estimated 44.8 million South Africans as of June 2004 [51], only 7 million have medical insurance. This leaves the public health sector to support the remaining 83% of the population not only for HIV specific treatments but also for general health support [23].

2.3.2 Treatment of HIV

Due to the high HIV prevalence in Sub-Saharan Africa as shown in Figure 2.1, there is an urgent demand for ART. ART treatment all over the world has proven to be an effective method of extending the lives of HIV positive individuals by increasing quality of life and reducing morbidity and mortality [14]. ART has been shown to suppress effectively the viral load (the total amount of HIV within a person) to barely detectable levels as well as to boost a patient's immune system.

The US and countries in Western Europe have been distributing ARV drugs and managing ART programmes for their HIV positive populations as far back as

the early 1990s [41]. However, the many challenges in ART require intensive specialised medical support, equipment and guidance for effectiveness.

Hence, ART access is limited with only 11 per cent of those currently requiring treatment in Sub-Saharan Africa being on treatment [70]. The estimates for South Africa show a similar picture and they are summarised in Table 2.4. Most African countries report that the demand for treatment cannot be met due to their lacking capacity to supply it. ART is a lifelong regimen with logistical challenges in the public health sector, such as the provision and distribution of medication, continuous patient monitoring and the communication of relevant data between patients and medical staff. It is possible that ICT can be used to assist in dealing with some of these challenges.

<i>Numbers on ART</i>	<i>Total needing ART</i>	<i>% on ART</i>
9,500 to 16,000	866,000	10% to 14%

Table 2.4: Summary of patients on ART in South Africa

In November 2003 the South African government initiated the process of planning a national roll-out of ARV treatment. However, it is difficult for hospitals and community clinics to order medication timeously and to collect relevant treatment information about patients. Rural clinics, and state-sector community health care centres in particular, lack adequate facilities, staff and equipment. Patients have to travel long distances in order to get medical treatment and counselling. Poor infrastructure has a negative effect on data collection and communication between doctors, nurses, local health care workers and patients, which can seriously endanger the effectiveness of ART.

Furthermore, ART itself is not simple treatment programme. It involves numerous drugs which could cause side effects, it requires a 95% adherence to be effective, and, in most cases, it has to be supported by strict time and dietary requirements. If guidelines are not strictly adhered to, the HIV+ person may build up resistance to the treatment, rendering further treatment futile.

The Cell-Life system intends to bridge these capacity limitations and infrastructure shortages. It links patients, health care workers, nurses, and doctors, and it increases the flow of accurate, current information.

2.3.3 The Home-Based Care Model

A successful model that the DTHF has developed for ART is centred on home-based care [4]. In order to help support a patient through the difficult starting phase of treatment and subsequent life-long treatment, much input and attention is required from medical staff. Because of the high patient load there are severe limitations on the numbers of doctors and nurses available to provide effective and sufficient follow up care and support. Therefore, the DTHF has set up a system to identify and train certain patients, who are good leaders, as home-based carers. Such individuals would be good learners who are adhering well to their drugs and who may even be unemployed.

They are offered a position within the site to train as “Therapeutic Counselors” (TC) or home-based carers. As a TC they go through a 3 to 6 month training programme that includes peer to peer counselling, HIV/Aids prevention, treatment and care support for ART and so on. The TC then becomes the home-based care support arm of the site, providing valuable treatment care and support on a regular basis to twenty or thirty ART patients within the TC’s community. Being from within the same community and also being on ARV therapy as fellow patients, means there is less of a communication barrier as the TC is able to understand firsthand the challenges and needs of the patients. The Cell-Life system supports the essential collection of data through cellphone menu applications that form a vital feedback link for the treatment process.

2.4 Information and Communication Technology (ICT)

Information and communication technologies (ICTs) have been noted as an important component in supporting development by organisations such as the United Nations (UN) and initiatives such as the “ICT for Development Platform” of the World Summit [72]. However, the use of ICTs requires some basic criteria to be in place in order to attain effective implementation and operation in the South African context. The role of ICT implementations specific to the support of healthcare delivery need to be:

- available, accessible and affordable for the target group
- appropriate to local conditions (e.g. language and ease of use)
- integrated in the target groups' lives
- sustainable over the long-term

Moreover, people need to be trained to use ICT effectively in order to attain and support healthcare processes such as ART. At present the state of GSM technology in South Africa is able to fulfil the above listed criteria. In South Africa the uptake and usage of cellular technology matches, and in some cases is proportionally greater than, those of developed countries. As of July 2004, South Africa is estimated to have 18.7 million cellphone users [12] out of a total population of 44.8 million [51]. This gives South Africa a cellphone usage level of 42% of the population which is comparable to a developed country like France where the cellphone usage is 41.7% of the population [11].

2.4.1 Global System for Mobile (GSM) communication

GSM is the global standard for digital cellular communication and it uses the 900 MHz, 1800 Mhz and 1900 Mhz bands. In less than ten years since the first GSM network was commercially launched, it has become the world's leading and fastest growing mobile standard, spanning 200 countries [21].

In South Africa, there are three GSM service providers that offer voice and data services which are summarised as follows [21]:

SMS (Short Message Service)

SMS is available on GSM networks allowing text messages of up to 160 characters to be sent and received via the network operator's message centre to another cellphone, or from the Internet, using an "SMS gateway". If the phone is powered off, or out of range, messages are stored on the network and they are delivered at the next available opportunity.

WAP (Wireless Application Protocol)

WAP is a specification for a set of communication protocols that standardises

the manner in which wireless devices (such as cellphones and radio transceivers) are used for Internet access.

WIG (Wireless Internet Gateway)

WIG gives WAP and SIM Application ToolKit (SAT) terminals access to WML-based applications for cellphone users.

USSD (Unstructured Supplementary Service Data)

USSD opens a live session over the GSM network to relay data as opposed to voice. The transactions occur during an open realtime communication session only.

GPRS (General Packet Radio Service)

GPRS offers ‘always-on’, higher capacity, Internet-based content and packet-based switching data services to cellphone users. This enables services such as colour Internet browsing, e-mail on the move, and powerful visual communications.

MMS (Multimedia Message Service)

MMS is similar to SMS but is a protocol that allows the communication of pictures and video clips to be sent over GPRS.

LBS (Location Based Services)

LBS allows requests from a cellphone user for its latitude and longitude position based upon triangulation of signal strengths from the GSM network tower grid, within a certain range and within a certain error.

Over the last decade cellphone technology has become easy to use, cost effective and widely accessible. As cellphone technology is chosen as the base technology in this project, it is interesting to note the connection between cellphone user prevalence and HIV prevalence by age group in South Africa. As shown in the Figures 2.2 and 2.3), the demographic distribution by age group of cellphone users and HIV prevalence follow a similar trend with a common peak age group of 25 to 35 years.

The comparison is between HIV prevalence data from the Actuarial Society of South Africa [1] and cellphone penetration (prevalence) data from the online mar-

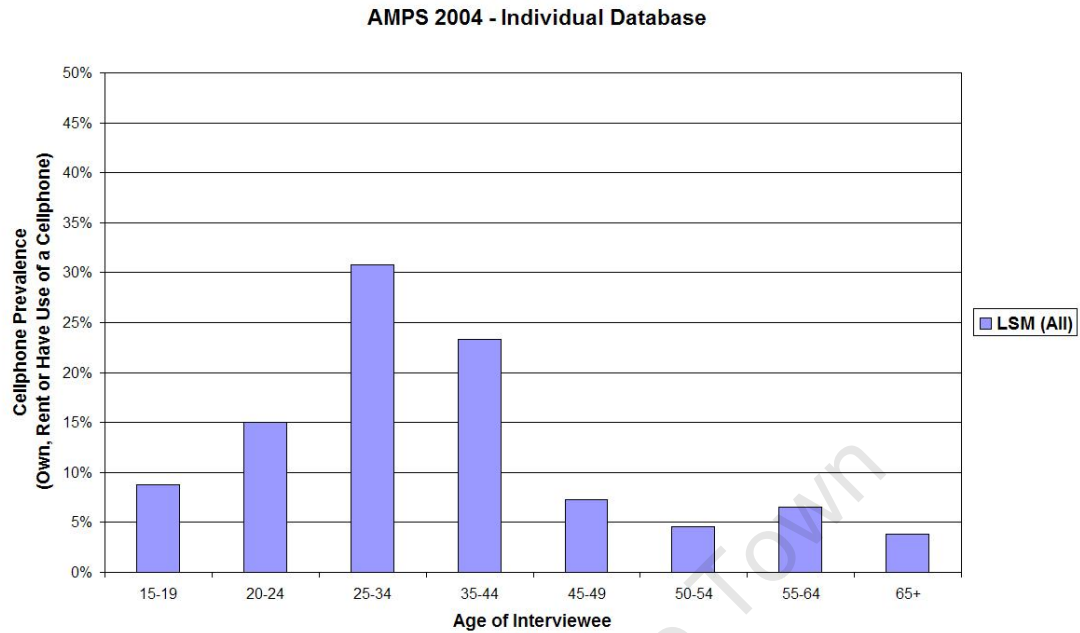


Figure 2.2: Distribution of cellphone users by age in South Africa across all LSMs [16]

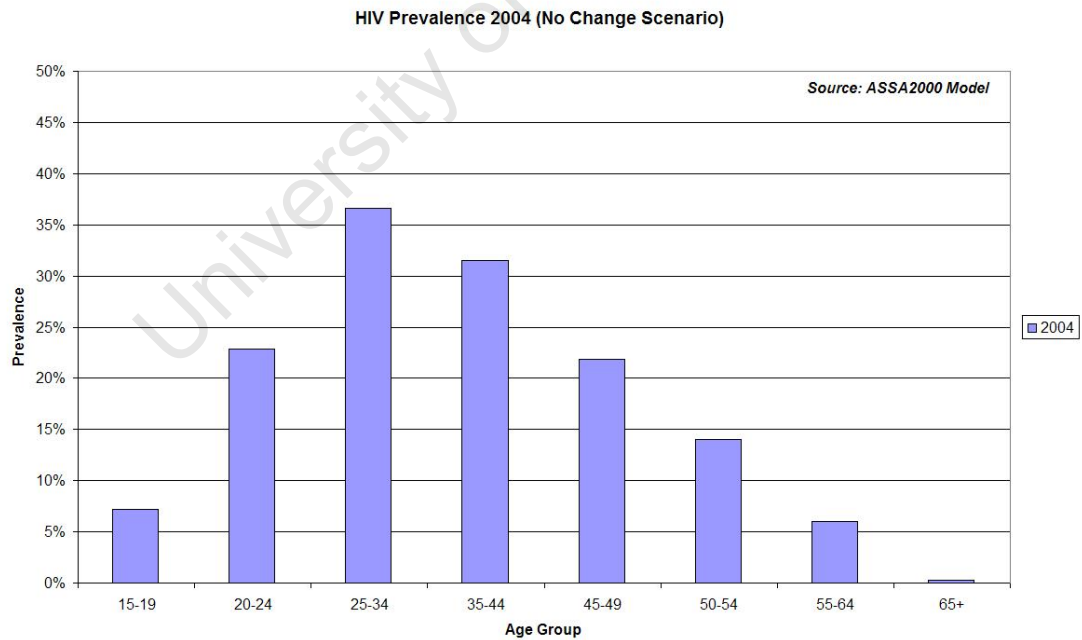


Figure 2.3: HIV prevalence in South Africa by age and sex in 2005 according to the ASSA 2000 Aids Model [1]

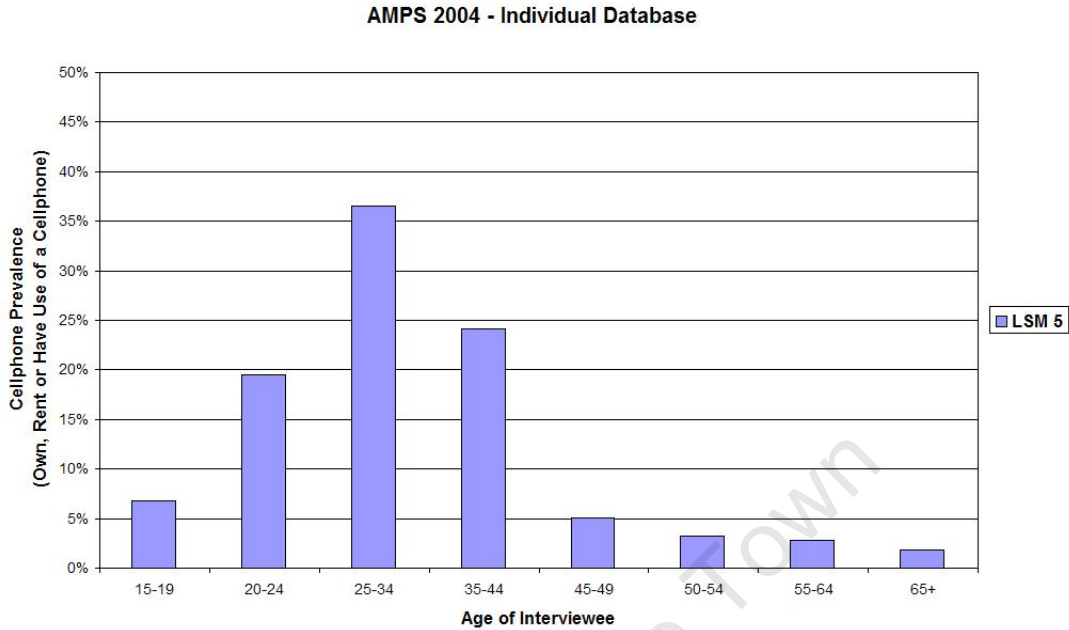


Figure 2.4: Distribution of cellphone users by age in South Africa at LSM 5 [16]

keting research company Eighty20 [16]. The HIV data is based upon a model that does not factor in any preventative and treatment processes and is called the “*no change scenario*”. As South Africa is a country of great disparity which is reflected in its having one of the highest macroeconomic measures of the Gini coefficient in the world [45], it is important to factor in the socio-economic influence on cellphone usage. A common measure for socio-economic status in South Africa is the living standards measure (LSM) developed by the South African Advertising Research Foundation (SAARF). As the public health sector caters mainly for people that fall in the LSM 1 to 5 categories, the end users of the cellphone menu applications are likely to be from this sector of the population. Therefore, Figure 2.4 is a graphical plot of the cellphone usage level in the South African population at LSM 5. When comparing this figure with Figure 2.2 it can be seen that the trend remains, however usage in the age groups below 44 is shown to increase slightly and this trend is consistent through LSMs 1 to 5.

2.4.2 The Internet

The Cell-Life system relies on the Internet as a core communication mechanism because it provides ART site staff with remote web application access to cell-phone collected patient data. Therefore, the availability, accessibility and cost of Internet access are important. Limitations to this access place limitations on the accessibility of the Cell-Life system. However, accessibility to the Internet is required only at the ART site administration point and not for every patient on ART. Patients are linked into the system through home-based carers using GSM cellular communication.

According to the International Telecommunications Union (ITU) there were 3.1 million South African Internet users as of December 2002 [27]. Of the 44.8 million South Africans, according to the 2001 census [51], 6.9%, or 1 in 14 South Africans, have Internet access. The use of the Internet is significantly lower than the use of cellular technology. The slow rate of growth of Internet users over the last few years can be attributed to the comparatively high costs associated with Internet connectivity in South Africa [17]. However, the vast majority of future Internet users will access the Internet for the first time through cellphone handsets in developing countries [56].

At present, Internet access is available via modem dialup, ISDN (Integrated Services Digital Network), Wi-Fi hotspots, ADSL (Asymmetric Digital Subscriber Line) and Satellite (wireless remote applications). High bandwidth optical fibre connections are also possible in South Africa, but access and usage is limited due to the high cost of such connectivity. In addition, progress has been made by government in rolling-out IT infrastructure and service delivery for the public sector through the recently privatised SITA (State Information Technology Agency) and through low cost rural wireless communication developments.

2.4.3 Open-Source Software (OSS)

The development of open source software (OSS) has growing widespread support, especially in the provision of Internet services. Open source is therefore regarded as a viable alternative to commercial software. The Cell-Life system is developed on an open source software platform using FreeBSD UNIX as the operating

system [18]. This for the following reasons:

- it has widespread distribution
- it is stable under high loads
- it has cheaper licensing costs (free in most cases)
- it has increased flexibility and scalability
- it has a community of support

The ability to develop software solutions and applications directly contributes to the growth of ICT and is essential to attaining the objectives of the system within a developmental context.

2.5 HCI Theory and Practice

As the components of the Cell-Life system are developed with the intention of supporting ART challenges in the public health sector, there is a very specific level of human interaction with the system. Such interaction is described as Human Computer Interaction (HCI). It is clear that the majority of end-user interaction with the Cell-Life system will be carried out via a cellphone handset or a desktop PC interface. The ease of use and operability of a system is directly associated with the targeted users' ability to interact effectively with the system. Shneiderman [46] states that at an individual level people's lives are changed through user interfaces allowing (for example) doctors to make more accurate diagnoses.

When considering the development and operation of a system in a holistic and systemic manner as followed in systems engineering, solutions are created in consideration of the complete system looking at all the various components and aspects. The interactive component in systems development has traditionally been one that has been overlooked. To ensure the design of effective systems, Shneiderman [46] states the importance of ascertaining the required functionality and reliability through the design process, and that, as systems evolve and grow, there is an increasing importance for standardisation, integration, consistency and portability.

2.5.1 Models of System Development

There are a number of system development models in existence and these are fundamentally based upon a range of guiding principles. However, all development models have a common time-based component being the development model life cycle concept. From a user interaction design point of view, Hix and Hartson [24] note the importance of empirical testing, iterative refinement and cost/benefit analysis, as well as verification and control of the development life cycle by management. As HCI is closely associated with the human or user component, many HCI system development models are user-centred in their design.

A typical software development process would be based upon a top-down approach beginning with systems analysis, followed by requirements specification, design, prototyping, implementation, and testing. As this is a stage by stage work flow process, it has been called the *waterfall method* and it is shown in Figure 2.5. It is regarded as the original model for software development. Further developments of this model have resulted in the *spiral model of software development* [24]. As the sequential process is never purely just one sequence, the spiral approach has been integrated into the model, with iterative feedback steps being carried out, as required, working towards a level of built-in self-correction.

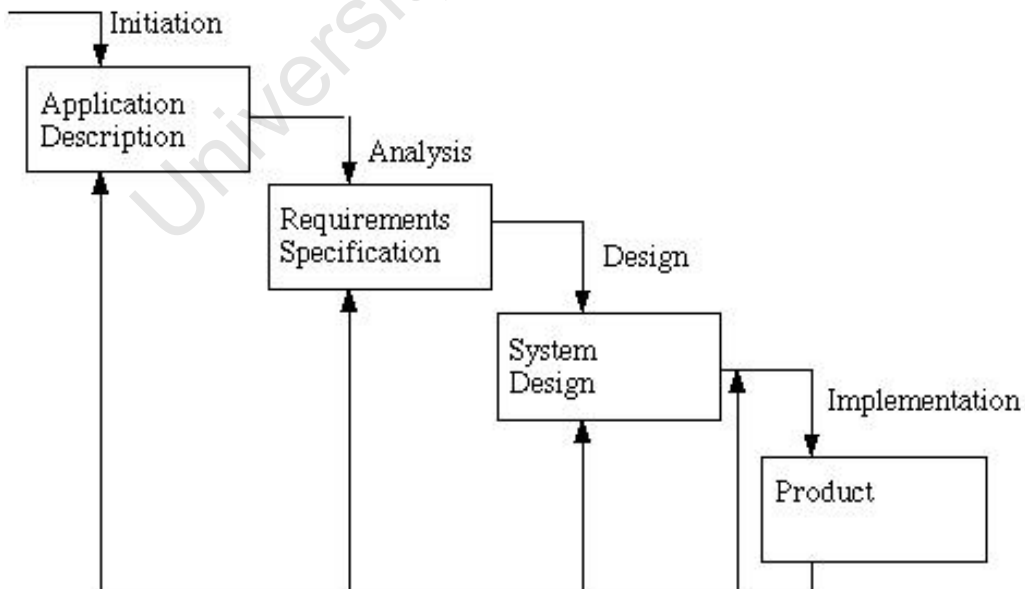


Figure 2.5: The original software development model, the waterfall method [26]

A model that is based upon user interaction development that is not only top-down but also bottom-up with spiral methodology iterations and does not require complete requirements specifications is the *star life cycle* developed by Hartson and Hix [24] and shown in Figure 2.6.

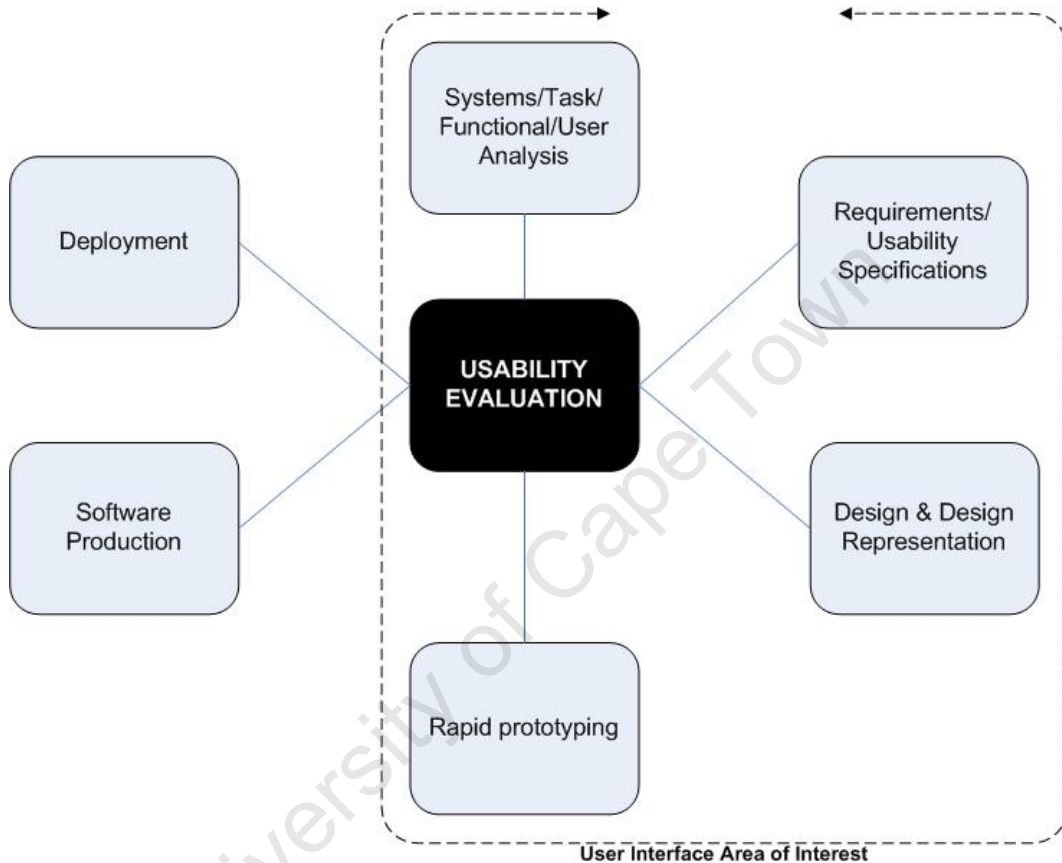


Figure 2.6: The star life cycle for user interaction development[24]

There is no sequential process in this life cycle model and a developer can start with almost any activity; however the vital central focus is usability evaluation after each stage of iterative development. Nonetheless, as reflected in the figure, there is no clearly defined end-point without the use of a quantitative usability specification control mechanism.

The *soft systems methodology* is also an iterative life cycle process but it is based upon separating the real world from the abstract one. Figure 2.7 summarises this model, with the most important stage being the the fifth one when the conceptual design is compared to the assessment and expression of the problem in stage two prior to any actual real world development.

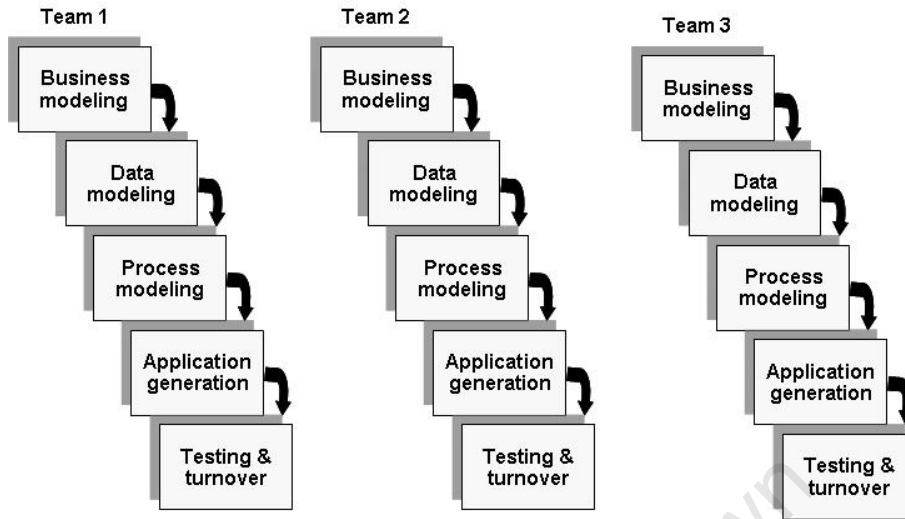


Figure 2.9: The rapid application development model (RAD) [52]

For the purposes of systems development in this project, the main methods of development used are based upon the *star model* in combination with the *prototyping model* in certain instances. This is due to the need for speedy delivery based upon the user's needs. In addition, public health ART medical staff are unaware of the potential benefits that ICT-based solutions can provide. Providing simple and quick prototypes for user evaluation and feedback results in the creation of a valuable participatory design process.

As the development model used in this research project is based upon a user-centred design, it is essential to cover the human factor aspects of the end users that have a direct and significant impact on the the development process.

2.5.2 Human Factors Theory

Human factors theory is a science that is derived from the principles of human behaviour [24]. The goal is to optimise human performance in dealing with interfaces through reducing errors, and increasing throughput, satisfaction, and user comfort. Shneiderman [46] states that there are five measurable human factors that are central to the evaluation of a system:

- *Time to learn* How long does a user take to learn the commands relevant to a set of tasks?

- *Speed of performance* How long does it take to carry out the benchmark task?
- *Rate of errors by user* How many and what kind of errors are encountered in the above two steps?
- *Retention over time* How well is knowledge retained and for how long?
- *Subjective satisfaction* How much did users like using various aspects of the system?

Shneiderman [46] further states that the lack of human factor considerations in design have resulted in concerns emanating from four primary sources:

- life-critical systems
- industrial and commercial uses
- office, home, and entertainment applications
- exploratory, creative and collaborative systems

Hix and Hartson [24] allude to four kinds of human factor information that heavily influence the product:

- user interaction standards
- user interaction design guidelines
- commercial style guides
- customised style guides

Guidelines are regarded as the commonsense side of user interaction design covering a very wide range of facets as follows summarised directly from the book “Developing User Interfaces” by Hix and Hartson [24]:

User-centred design

Know the user and practice user-centred design. Involve the user in the design process through participatory design. Also predict or anticipate errors and head

the user away from such an error, resulting in a reduction of errors. Optimise user operations, making frequent operations as efficient as possible with fewer steps. Move and keep the locus of control with the user rather than the computer and make getting started as simple as possible with information that makes up no more than one page.

Mental model of the system

Give the user a mental model of the system, based on user tasks. Visual clues are especially effective in communicating the system model to a user. An example is the scroll bar within a window that informs the user of the size of a file as well as the user's current location within the file.

Consistency and simplicity

Be consistent and keep it simple. Both of these aspects have a direct impact on the usability of a system. Complex tasks should be dealt with in a manner that makes their operation simpler for the user.

Human memory issues

Recognise the limitations of human memory when providing users with information, allowing users to recall required information when needed. The rule of thumb is the “seven plus or minus two chunks” developed by Miller in 1956 [34]. A chunk is regarded as a basic unit of information and therefore on average a person is able to remember seven basic units of information.

Cognitive issues

Direct cognitive processes minimise mental transformations. A good example is the shortcut for the command “Copy” being “Control - c”. Real world analogies are also important as shown in the graphical interpretation of a folder on a operating system desktop for the storage of files.

Feedback

Informative feedback to users with appropriate status indicators are important. Examples are the hour glass pointer display common in windows-based operating systems meaning that the system is currently carrying out a process.

System messages

System messages are a form of feedback to the user and should therefore be user-centred in wording. They should also be positive, and non-threatening in manner. Error messages should be specific, constructive and also allude to the system for blame rather than the user.

Anthropomorphisation

This is the process of attributing human characteristics to non-human objects and it should be avoided due to the high risk of doing so badly and this resulting in negative user reactions.

Modality and reverse actions

The use of different modal states needs to be carefully considered and justified and user actions should be easily reversible.

Getting user's attention

Getting and attaining the user's attention through sound judgement. Audio and graphics can be used in different ways and colour has critical design impact requiring the consideration of the user.

Individual user differences

Accommodating individual user experiences, differences and levels.

Finally, consideration should be given to the human diversity that exists within the final user group of the system. This diversity includes aspects such as [46]:

- physical abilities/disabilities and workplaces
- cognitive and perceptual abilities
- personality differences
- cultural and international diversity
- elderly users

Display issues

Maintaining the display design inertia based upon a standard layout. Organising the screen to manage complexity such as removing unnecessary information and developing a balanced easy to read display layout.

With a systems development model at hand and a review of the potential human factors covered, the following section is a review of the formal stage by stage development process followed in this research project.

2.5.3 Systems Analysis, Design and Testing

This research project has followed a specific user interaction design process described by Hix and Hartson [24] and the HCI Glossary [22] and it is summarised as follows:

User analysis:

This is combining the human user's specific functions and tasks, resulting in the defining of classes of users or user profiles.

Requirements analysis:

This is the formal process of specifying the design requirements for the system. Requirements analysis is based upon the user needs and user analysis.

Task analysis:

This is a detailed description of the tasks and methods in using a system. It is the process of investigating a problem by breaking down the tasks that potential users of a system carry out into system functionality.

Conceptual and functional design:

Based upon the above steps, a conceptual design of the system at the high level is developed. This is then translated into a functional design specific to the internal technical functions of the system.

Documentation:

This is the process of documenting the development and the implementation

process of the system and the highlighting any problems encountered and the solutions found.

Usability testing:

This is the testing phase of the system development, where testing with users is carried out to determine if the system meets a predetermined, quantifiable level of usability with respect to user tasks. Various test methods are used, which are specific to the different components of the system.

2.5.4 Theory of Menu Design

In the context of this research project, the background review of menu design theory is covered in order to support the cellphone menu application design process. The use of menus in systems and software development is an integral part of the HCI, leading to the ease of use of simple to complex tasks. The range of menu options is wide, from push-button and radio buttons to dynamic menus. Menus provide a structured interface for the user and they are useful in combination with data collection through form fill in. Menus provide users with explicit clues and they reduce the need for remembering commands. Menu design may work towards ease of use, but it is difficult to develop interfaces without careful consideration and testing for design issues, such as [46]:

- task-related organisation
- phrasing of items
- sequence of items
- graphical layout and design
- response time
- shortcuts
- online help
- error correction
- selection mechanisms

The primary goal for menus and form fill in is to carry out user tasks in a sensible, comprehensible, memorable and convenient manner. Meaningful organisation is therefore necessary to give users an insight into the contents of a menu in a logical manner. This could be further aided by chronological, numeric or alphabetic sequences as an example. Figure 2.10 is a summary of the range of available menu design options including; single, linear sequence and multiple, tree-structured, acyclic and cyclic menus.

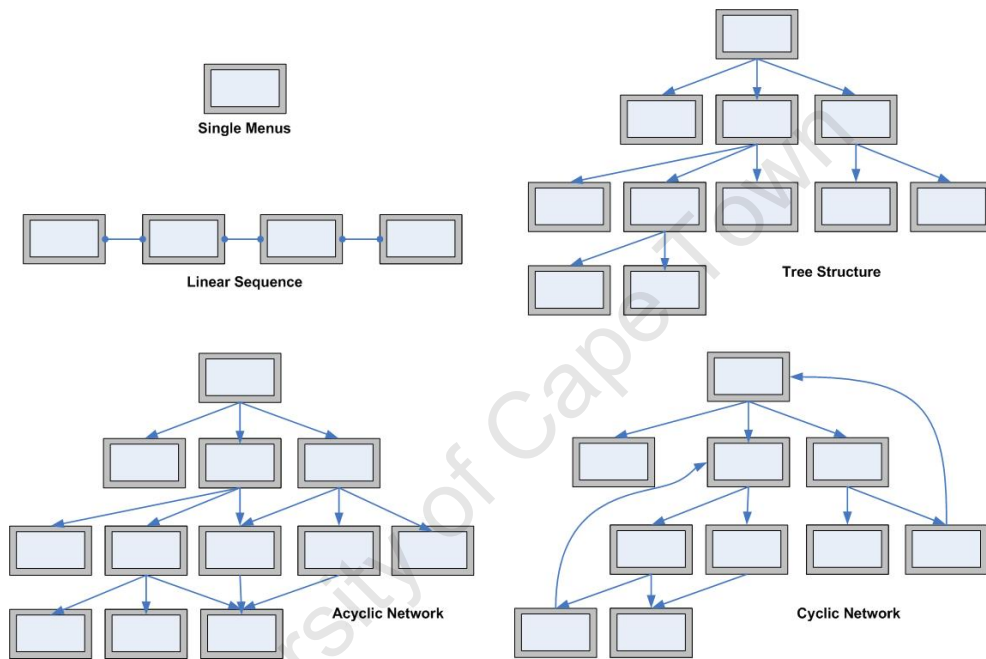


Figure 2.10: An overview of different menu systems [46]

Research in 1982 by Card [46] resulted in a comparison of the speed of response to alphabetic, functional and random menu options. The outcome of the research showed that alphabetical sequences were four times faster accessed than random ones, with the functional response time in between the two.

High frequency options can be organised in descending frequency with faster response times, however lower frequency option response times increase and become more disruptive. When creating font menus it was very successful to place the three most popular fonts for display from experiments and field studies at the top, with the remaining fonts in alphabetic order [46].

System response times and display rates are also important to consider with regard to web-based applications but less so with respect to desktop applications,

as computing power has increased significantly to render this problem nonexistent. An important balance that must also be attained is the depth of menu structure versus the length of options in each menu. Shneiderman noted that very little empirical validation of menu layout experimental research had been conducted, resulting in most of the information in this area being subjective judgements. However, it was noted that attention from the user's perspective should be taken into consideration when developing menu titles, phrasing menus, and designing and laying out graphics.

2.5.5 User Interface Specification

The successful design and architecture of a system usually takes place prior to the actual construction or development process, and then once in development further changes are made. In order to provide a framework for designers and software engineers to communicate and collaborate, a standard default language for specifications is needed. This section is an overview of the following five methods directly summarised from the book "Designing the User Interface" by Shneiderman [46]:

- grammars
- menu-selection and dialog-box trees
- transition diagrams
- statecharts
- user-action notation (UAN)

Grammars

Backus normal form (BNF) is used to describe programming languages using nonterminals for high level components and terminals for specific strings. A nonterminal could be a person's name with the name consisting of a string of characters as shown as follows:

```
1 <Name> ::= <string>
2 <string> ::= <character>|<character><string>
3 <character> ::= a|b|c|d|e|f|...
```

Overall, BNF has been adapted into variant forms used for example in UNIX commands and by Shneiderman [46] for *multiparty grammars* where nonterminals are labelled by the party that produces the string.

Menu-selection and dialog-boxes

The *menu selection tree* is a simple structure that can be used to guide designers and users alike. However, there are limitations to this graphical representation of a large system due to its size and complexity as well as its inability to reflect error handling and detour links. An overview of menu structure options is covered in Section 2.5.4.

Transition diagrams

Transition diagrams have a set of *nodes* that represent system states and *links* represent the transitions between states. An example of a restaurant review menu system is shown in Figure 2.11. In this example there are a number of choices to follow with the flow between states represented by numbered links. Adapted versions of transition diagrams exist but complex systems can be difficult to specify in this manner and they become more difficult to read.

Statecharts

Statecharts have a grouping feature using “round-tangles” which can hold repeated transitions. Extensions to this concept have included concurrency, interrupt events, user actions and even graphical representations of the visual states of a system. Figure 2.12 is an example of a statechart of a simplified bank transaction system.

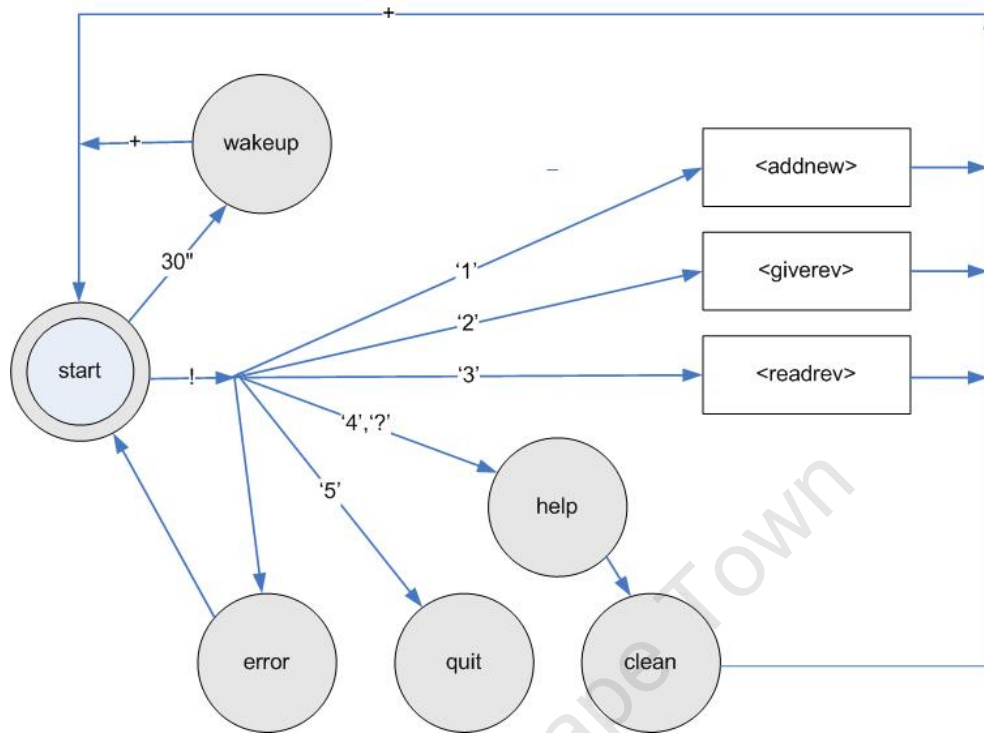


Figure 2.11: A transition diagram for a simple menu system [46]

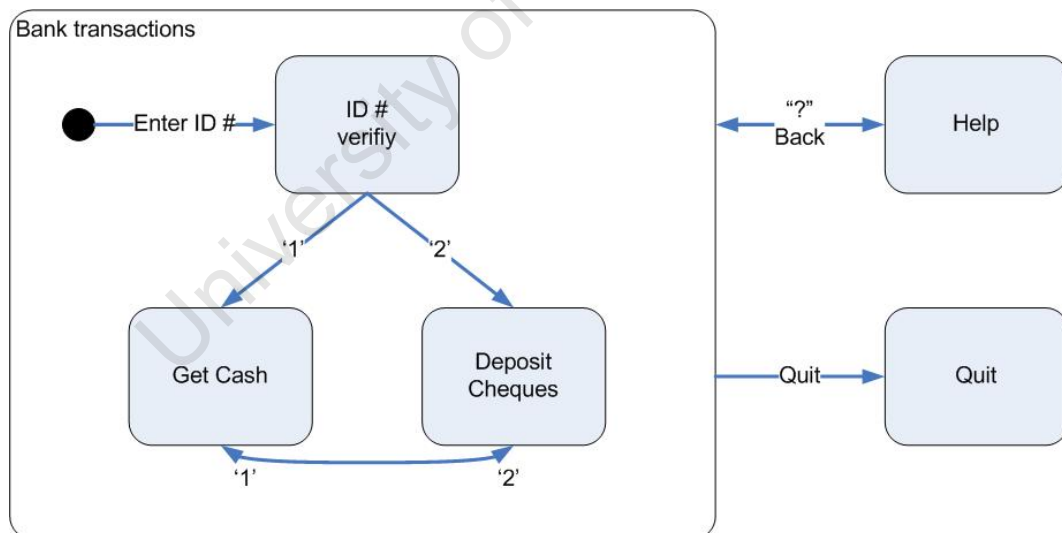


Figure 2.12: A statechart of a simplified bank transaction system showing grouping of states [46]

User-action notation (UAN)

UAN is a user- and task-orientated notation for describing the behaviour of the user and the interface as they perform a task together [24]. User actions and

feedback from the interface with state changes are represented at the lowest level of an integrated sequence through time-related user behaviour. UAN is supplemented with various components including transition diagrams, scenarios and pictures. A combination of representation techniques results in a comprehensive tool for the specification and design of HCIs. Representations in UAN include movement of the mouse cursor to the click and release of a mouse button.

In the development of cellphone menu applications covered in Chapter 3, transition diagrams and statecharts are used.

2.5.6 Theory and Practice of Web Application Design and Evaluation

Web application design

Extensive research has been carried out since the inception and expansion of the Internet providing online access to information. Through this research, errors and design flaws have been highlighted. From a general user point of view web application design has been centred around issues of usability. In the business context these issues translate into financial and productivity inefficiencies. An article by Jakob Nielsen and Kara Pernice Coyne, leaders in the field of web site usability, point this out in the online article *A Useful Investment*, where they justify the costs to businesses associated with usability testing in the long run [36].

Other problems noted were the limitations associated with web browser interaction as well as a lack of standards and user-centred simplicity to name a few. Many useful resources and guiding points from Jakob Nielsen's web site (www.useit.com) have been reviewed and incorporated into the development of this research project [38]. The following are important relevant points from Nielsen's online *Top Ten Mistakes* lists:

- Not changing the colour of visited links within a web site and not keeping links standard
- Non-scannable text

- Fixed font sizing through CSS and font legibility
- Page titles with low search engine visibility
- Anything that looks like an advertisement
- Violating design conventions - keeping consistent with the general online web site style
- Opening new browser windows through hyperlinks
- Not answering users' questions
- Browser incompatibility
- No contact or company information

Web application and system evaluation

To evaluate the usability of a web site, the *system usability scale (SUS)* by John Brooke is used [7].¹ The difficulty in such evaluation is the lack of absolute measures of usability resulting in the development of broader more general measures. Low cost assessments that are useful in industrial systems evaluation are based upon “quick and dirty” methods. Guidance from ISO9241-11 suggests that usability evaluation should cover [7]:

- effectiveness
- efficiency
- satisfaction

The SUS is a simple ten item scale covering a global view of subjective assessments of usability, with each statement evaluated over a 5 point range scale. The SUS is generally used after the respondent has had an opportunity to use the system being evaluated, recording immediate responses. SUS scores have a range of 0 to 100.

¹The SUS document can be found in Appendix B

At this stage the background information relevant to this project is complete and this chapter is followed by five chapters that cover the research and development of various components of the system, starting with the cellphone menu application.

University of Cape Town

Chapter 3

CELLPHONE MENU APPLICATIONS

Cellphone menu applications are developed to support the ART patient aftercare followup by home-based carers. Based upon user feedback from both the cellphone users and the ART site management, a number of problems and modification requests were identified. This chapter describes the design and development of three new cellphone menu applications. The original WML code was only used for references purposes and new code was written using additional functionality to meet the user requirements. The chapter ends with a review of the comparative usability testing and results of the current and the new cellphone menu applications.

3.1 User Analysis

The home-based care arm of a ART site is a support network for ART patient aftercare. A key responsibility of its function is to provide feedback and reporting to the medical staff at the local clinic. This allows a larger patient base to be remotely monitored, specifically in the area of ARV drug adherence.

Prior to the development of the first version of cellphone menu applications, all reports to the ART clinic were carried out on paper. Custom designed forms or note books were issued to home-based carers for data collection during patient

home visits. This data was then submitted weekly to the local clinic and then periodically to the DTHF. At the DTHF the information on the forms was captured into a database, providing medical staff with patient data giving additional insight into the patient's ART progress. However, a number of problems were encountered with this method. Firstly, paper based information was sometimes lost or captured with errors through the physical transfer from patient visit to final data capture. This was not only a loss to the site of valuable monitoring data, but it also put patient confidentiality at risk. Secondly, the entire process from the point of data collection to data capturing took from one week to a number of weeks. Such delays were critical with respect to timely responses to potential patient ART complications.

This user analysis makes it clear that there are two types of users within the system. The first user is the home-based carer using the cellphone menu application for patient after care. This user is referred to as the *cellphone user*. The second user is the ART site medical and administration staff who access and analyse the collected data for decision making. This group is referred to as the *web user* as they access the collected data using a web application.

The development of the first prototype remote cellphone data collection system was to address the challenges and flaws in the paper system. The growth of GSM coverage and increased accessibility to the technology was a motivation for this choice. A cellphone menu application to collect five areas of data was developed, feeding collected data over SMS directly into a central database. Based upon the reporting data requirements of the ART site, the system was implemented and operated for 6 months. The tool was successful in addressing the challenges identified originally but resulted in a new list of problem areas that make up the requirements analysis that follows.

3.2 Requirements Analysis

Figure 3.3 is a menu structure overview of the current menu application. Problems with the existing menu, based upon discussions and interviews with cellphone and web users summarised as follows:

- *Having one menu with five separate data collection components meant repeating the data collection process multiple times, with the adherence component alone repeated three times for each of the triple therapy ARVs at each home visit.* To ease the process of data collection for users, the design of the system is to be reviewed with the objective of simplifying the data collection process (functional).
- *Each menu component required an SMS data submission resulting in a minimum of four and a maximum of nine SMSs per home visit significantly contributing to high communication costs.* The requirement is to improve the cost effectiveness of the overall data collection process (non-functional).
- *There was a newly identified data collection requirement of socio-economic data that was regarded as important to monitoring and assessing the potential success of patient ART.* The newly required data must be integrated into the menu system taking into consideration the impact on the prior points (functional).
- *A greater detail of adherence data was required specific to identifying the adherence problems.* The adherence data collection component is to be reviewed to include and integrate the additional data collection (functional).

3.3 Task Analysis

In order to carry out a task analysis, the high level requirements are examined and broken down into the specific tasks a user would carry out. This process provides insight into the development of the required functionality. Some tasks are to be carried out by the user alone being *manual tasks*, and others are carried out by the system alone being *automated functions*. Each user task should link to a system function. Table 3.1 is a summary of the user specific tasks followed by the respective system functionality.

Tasks	System Functionality
<i>Carry out the data collection process via patient home-based care visit</i>	Manual user task
<i>Interact with the cellphone menu application in an easier manner than currently</i>	Improve the cellphone menu application usability
<i>Insert data into the cellphone menu application</i>	Collect and store data in variables within the cellphone menu application
<i>Submit data from the cellphone menu application to the Cell-Life database</i>	Collate the data within the application and transmit these to the database
<i>Carry out data collection for 3 ARV drugs in one application process</i>	Review and redesign the application to collect data for all three drugs at once
<i>Collect data for multiple symptoms in one application process</i>	Review and redesign the application to collect data for multiple symptoms at once
<i>Collect a defined set of socio-economic data from the patient</i>	Add the specified socio-economic dataset to the menu application
<i>Collect a defined set of adherence problems data from the patient</i>	Add the specified adherence dataset to the menu application
<i>Carry out the complete data collection process using fewer SMSs</i>	Make the above listed changes to the system in a manner than improves the overall cost effectiveness of the application through more efficient use of SMSs

Table 3.1: Task analysis summary - cellphone menu applications

3.4 Conceptual Design

In order to clearly define the existing and required functionality of the menu application, a conceptual design of the proposed application is developed based upon an analysis of the current system, mapping all the sequential operations. This provides insight and guidance into the design of the new proposed system.

Figure 3.1 is a statechart of the current cellphone menu application from a user functionality point of view. Figure 3.2 is a statechart of the proposed cellphone menu application incorporating the steps highlighted in the requirements analysis.

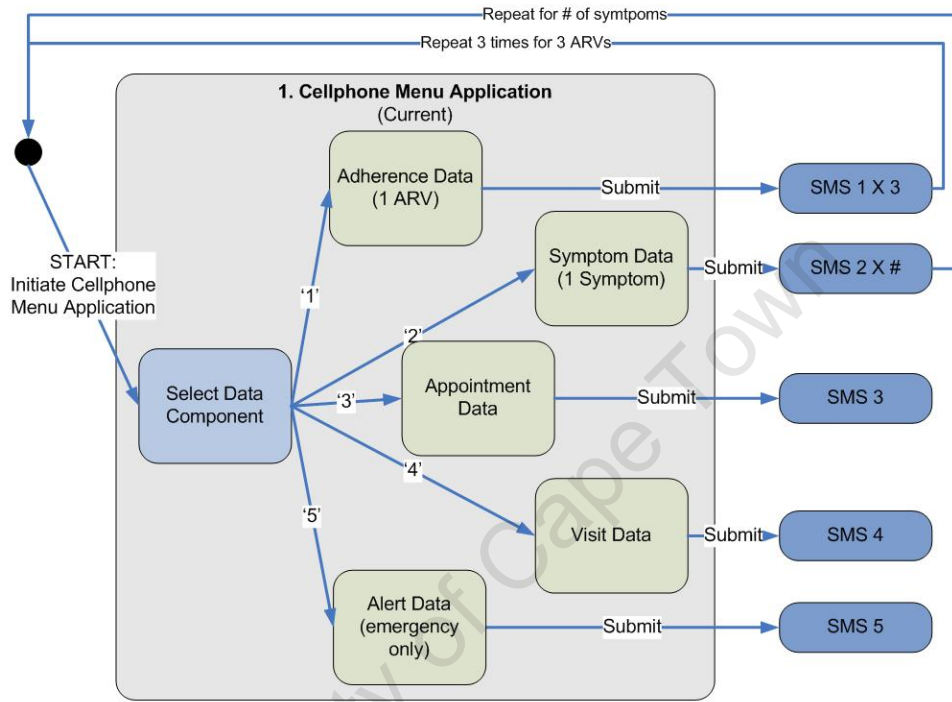


Figure 3.1: Statechart of the current cellphone menu application

In developing the conceptual design of the system it was essential to take into consideration the human factors of the cellphone menu application users. The first step towards achieving this has been based upon a user-centred design process. The following human factor points were taken into consideration during the design process:

- retain consistency and simplicity
- recognise memory limitations based upon the seven “chunks” rule
- use cognitive methods
- maintain a standard display layout
- provide reverse actions and a mental model of the system

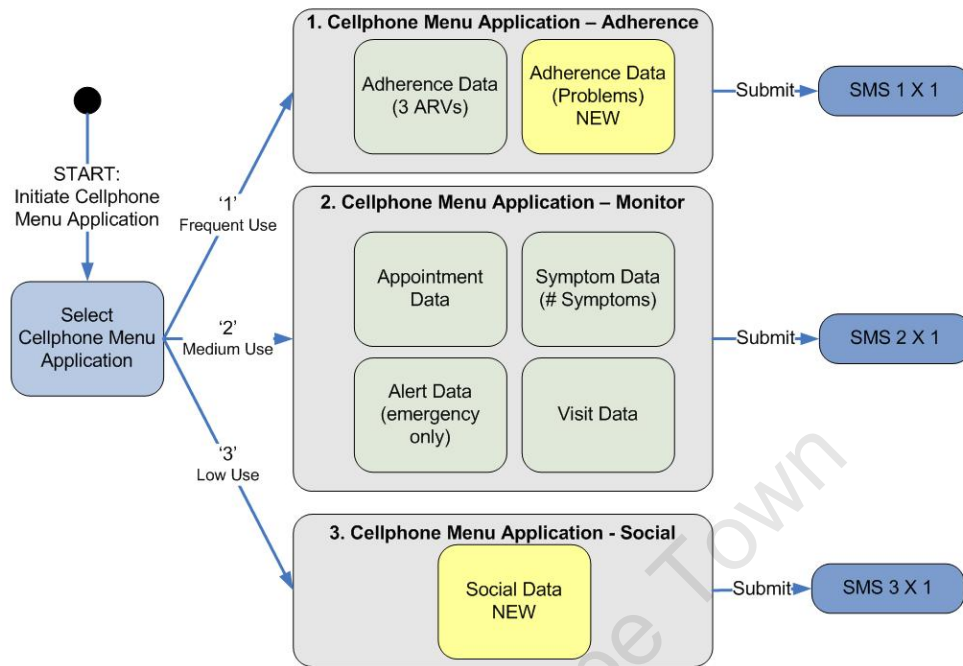


Figure 3.2: Statechart of the proposed cellphone menu applications

Consistency was retained through using the same logical data flow and standard display layout. Simplicity was improved by allowing increased data collection with fewer data submissions. Cognitive methods were used by using abbreviated word associations with options in the menu display. The new application provided for a form of reverse action in that the closed loop operation of the menu allowed data collected in error to be re-collected, without having to leave the menu and start again. Mental models were to be presented to users by providing them with high level menu diagrams. Such diagram will give a complete overview of the menu application functionality that could be compared to the original paper-based data collection form. Lastly, the challenges with respect to memory retention were addressed through separating the single application into three separate menus based upon the frequency of use; also providing the user with the opportunity to carry out the data collection on three ARV drugs within one menu.

All data was collected in a maximum of three collection menu processes and submissions, rather than through five data collections paths resulting in up to nine submissions if a patient is on triple therapy ARVs and suffering from at least

three symptoms. The process of remembering which data was collected was also simplified in the new system.

3.5 Functional Design

At this stage the conversion of the conceptual model, as shown in the previous statechart of the cellphone menu application, into a functional model based upon the technical options and components was carried out. The first stage was to assess the technical systems behind the existing application.

The chosen cellphone menu application technology was WIG and background details to this technology were covered in Section 1.2.2. Alternative options available to implement such a menu application structure on a cellphone handset for data collection are:

- Unstructured Supplementary Service Data (USSD)
- Wireless Application Protocol (WAP)
- Multimedia Messaging Service (MMS)
- General Packet Radio Service (GPRS)

The following are reasons as to why the alternative GSM communication methods were not suitable in comparison to WIG:

USSD

The USSD interface is based upon the serving of a dynamic menu structure to the cellphone handset. The connection time is limited by the service provider. The chosen service provider period is capped at two minutes and is billed in twenty second segments. The adherence menu alone has 25 data variables which would require a user to enter each variable within 5 seconds, with the time per variable being further reduced in the event of errors. In addition, the comparative cost of a two minute USSD session is 50% more expensive than a peak period SMS, at R1.90 relative to R0.85 in June 2004.

WAP

WAP requires a user to firstly have a WAP enabled cellphone and then to make a dialup connection onto the Internet. Once online, WML pages could be accessed for data collection. The WML pages accessed would be very similar to the WIG applications that can be installed on the SIM card. There would be no direct benefit to such a data collection process other than the ability to make changes to the WML application on the server side. However, the cost of making the WAP Internet connection and the increased complexity for the user and replacement of the protocol by GPRS, make this option unviable.

MMS and GPRS

Taking advantage of MMS over SMS in the communication link would require a GPRS connection, and WIG applications are not able to make MMS data submissions from a handset. This would require a GPRS enabled cellphone, and possibly menu applications developed in Java using a platform such as Java 2 Micro Edition (J2ME) for the application development. The cost of GPRS for prepaid cellphone users is currently ten times more expensive than that of contract users, and GPRS Java enabled cellphones are more than double the price of the current chosen WIG enabled cellphones. Therefore, as at June 2004, such an option would not be possible based upon the increased set up and operational costs.

3.6 Documentation of Implementation

The implementation of the chosen conceptual and functional design was carried out through development of the cellphone menu applications on the WIG platform. WIG menu applications were written for implementation on a cellphone 32K SIM card in WML. To do this, the WIG Application Creator (WAC) from SmartTrust [49] was used. The WAC allows a WIG application to be programmed and tested on a cellphone simulator. Applications are limited to 1 Kbyte (1024 bytes) in size by the GSM operator as the extra SIM memory is divided into 1K memory banks. Menu applications can be created using WML

in a variety of programming styles.¹ Once programmed and tested on the WAC cellphone simulator, the WIG application is sent to the GSM network operator for implementation on the WIG server and download installation on to the SIM card.

After a number of iterations and reviews, the new cellphone menu applications described in the Conceptual Design Section 3.4 and represented in Figure 3.2 were developed. Figures 3.3 and 3.4 are the detailed menu structure view of the current and new menu structures. It can be seen that in order to collect multiple sets of information within one menu and SMS, the current tree menu structure had to be replaced by a cyclic menu structure.

There is space for a maximum of eight multiple 1K applications on the SIM card, but the GSM network operator limits this to a maximum of three applications, and therefore the new revised application is separated into three menus to accommodate the required data collection. The choice of menu content was based upon frequency of usage with the most used components of the original menu placed into a *Monitor Menu*. The adherence data collection which is collected at irregular intervals was placed into a revised *Adherence Menu*, shown in Figure 3.4. Lastly, the socio-economic data was placed in the *Social Menu*.² All WML programming was carried out according to the guidance and specification of the WML Version1.1³. When comparing Figure 3.3 with Figure 3.4, it can be seen that the following changes were carried out in the new menu⁴:

- The original method of drug selection did not cater for multiple triple drug selection. Also, the implementation of WML on the SIM card did not cater for temporary variables, which with variable substitution could solve the problem. Therefore, a simple numeric input based upon a screen display of numerically referenced drugs was used.
- The menu was designed to flow in a manner that includes all components. However, at the start of the menu, the first level allows the user to skip a menu section and proceed to the final submit (SMS send) option. This

¹Samples of the WML code, cellphone and WAC screen shots can be found in Appendices A.6.1 and A.11

²The *Monitor and Social Menu* charts can be seen in Appendix D.1

³The DTD can be found in Appendix A.6.1

⁴The WML code for all three new applications can be seen in Appendix A.6.1

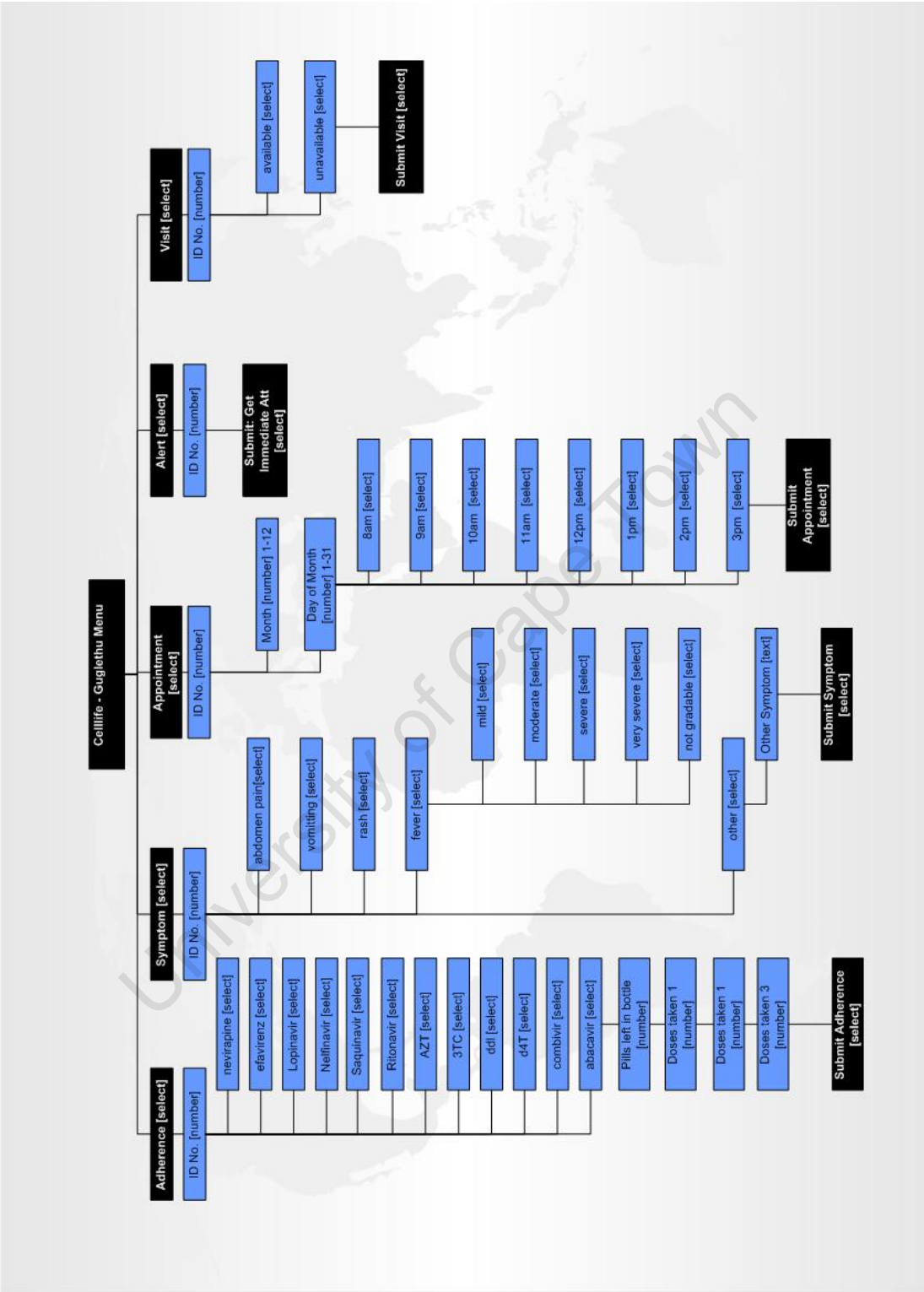


Figure 3.3: Tree Structure of the Current Cellphone Menu Application

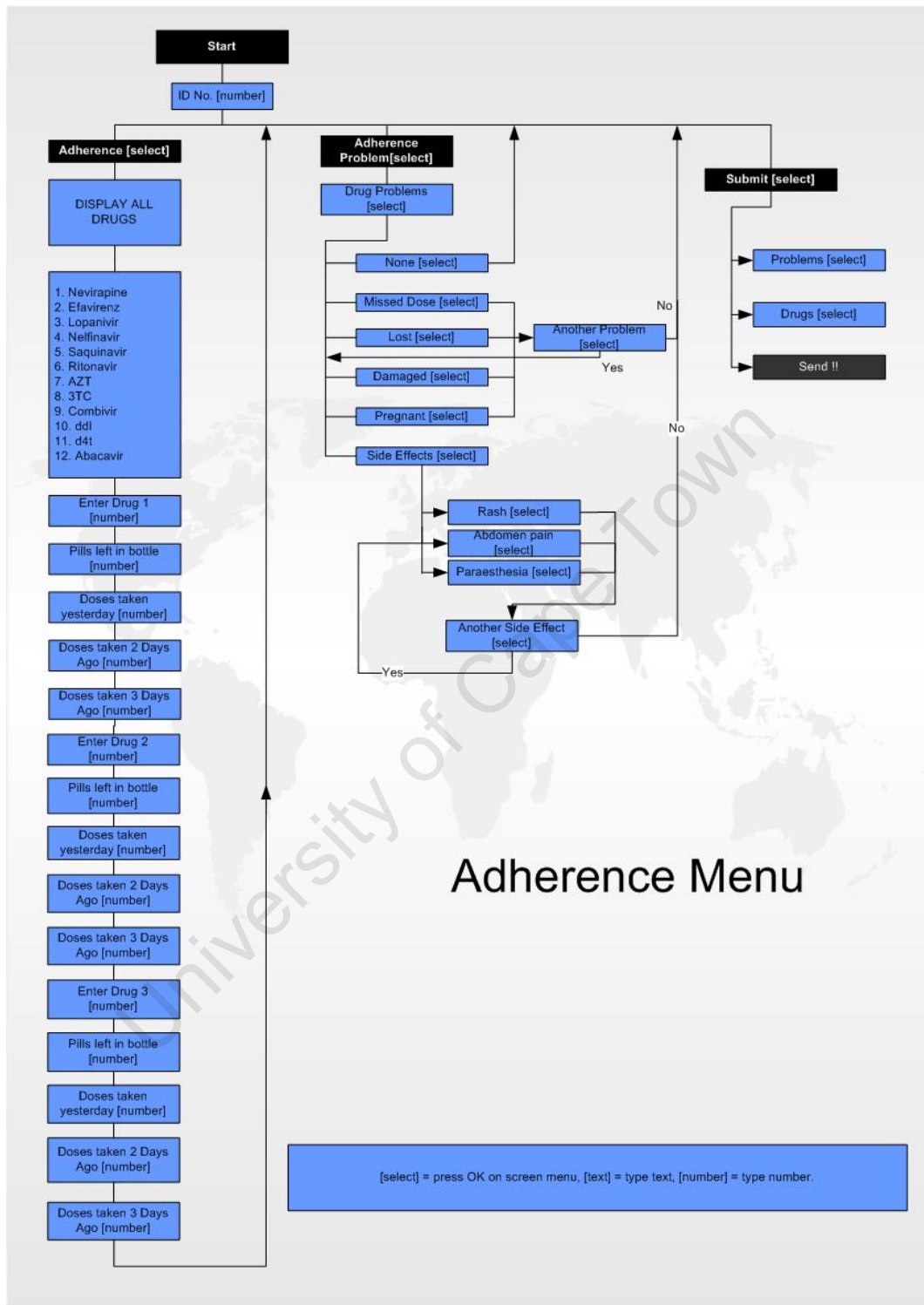


Figure 3.4: Cyclic Structure of the Proposed Adherence Cellphone Menu Application

also allows for the patient *ID No.* to be entered only once, instead of five times as in the original menu.

- Extensive WML and WIG standard implementation problems were found with the GSM network operator and the cellphone handset manufacturers. Neither party at the time of this development had implemented complete and consistent standards. Therefore, extensive time and energy was spent developing WIG applications using the WAC in terms of the specification, only to find incompatibilities and bugs with respect to the WIG platform or cellphone handset.

Literature is available with respect to cellphone handset WIG specification implementations, but the problems with the GSM network operator are independent and unique. Therefore a document called the WML programming reference guide was developed in collaboration with M Parker and D de Jager⁵. The guide also includes a standardised list of all possible variables and their corresponding alphanumeric reference, a standardised method for the declaration of variables, commenting, indentation and a check list for common specification implementation problems.

- The program structure was altered to allow multiple entry of options such as *adherence problems*. Also, at the submit option, the user can review entered data prior to final submission. This gives users the ability to check if the collected information is correct prior to submission.
- An additional component under the submit section, not shown in the menu structure diagram, is a *Reset* option, which resets the menu, allowing the user to restart the menu in the event of uncertainty or errors in the data collection.

3.7 Usability Testing

The usability testing process was carried out with a group users similar in age to the home-based carers and with no first hand experience of the cellphone menu applications. However, the user group had an average education level that was

⁵This guide is shown in Appendix A.6.2

higher than that of the home-based carers. The process involved the following steps:⁶

- Introduction and background to the system (cellphone and web applications)
- Collection of participant background information (Age, Gender, Education Level, Computer Experience and Cellphone Experience)
- Participant consent
- Training and practice on each application prior to the testing process
- A testing process based upon a specific set of tasks followed by questionnaire evaluation of HFT (Human Factor Test) questions, a SUS (System Usability Scale) questionnaire and, finally, a general user evaluation questionnaire

Testing was carried out on the new menu application and the current menu application, referred to as Applications A and B respectively to the users during testing. However, the current menu application was not available on any SIM cards and a backlog at the GSM service provider meant that the only tool available for testing the current menu would be the WAC cellphone simulator. Therefore both applications were tested on the WAC simulator, as well as actual cellphone based testing with the new application. Each user was given a chance to go through a short training and practise session followed by a testing period. In the test, each user was given two sample patient visit datasets to collect with the application at hand followed by the questionnaire evaluation. This testing process was repeated for each of the following applications with a different pair of patient datasets:

- Application A1 - New Menu (PC WAC Simulator)
- Application A2 - New Menu (Cellphone)
- Application B - Current Menu (PC WAC Simulator)

⁶The questions from the usability testing session can be found in Appendix B

As there was a total of 15 people in the testing session, the group was split into two groups A and B, allowing for a typical training session of less than 10 users per trainer as used in the pilot site.⁷

As noted by Shneiderman [46] there are at least 5 important human factors to take into consideration during testing:

- learning time
- speed
- rate of errors
- retention over time
- subjective satisfaction

All five of these have been catered for in the testing process except for retention over time in the long-term, as the testing process was carried out once and it was not possible to track and test errors from the WAC simulator for the current menu. However, short-term memory retention was tested as the new menu was tested twice by each group, once on the PC WAC simulator and once using a cellphone.

3.7.1 Overview of the WAC Simulator

The WAC has a cellphone simulator which is used throughout the development process, with the simulator providing a valuable testing facility. However, there are limitations to simulation capability of the WAC software, which are found through experience. In reality cellphone handset manufacturers and GSM network service providers implement varying WIG standards resulting in widespread incompatibilities. An example of this is that WML has a feature which displays the name of the displayed screen (each screen is called a *< card >* in WML) at the top of the cellphone display. This is a feature which is simulated in the WAC. However, when implemented on a SIM card installed on the Nokia 3310,

⁷Complete details to the testing process and test results in a raw data format can be found in Appendix B

the $\langle card \rangle$ name is not displayed. This is due to the fact that the Nokia 3310 is an entry level cellphone in the Nokia range and it uses a simpler LCD which is not able to display the screen name. The Nokia 5510 is a cellphone that does offer this feature and it displays the $\langle card \rangle$ name correctly. As Nokia 3310 cellphones are the chosen cellphones in the Cell-Life system, the menus are designed to work optimally on the Nokia 3310. In order to fully test the developed menus on a cellphone, a request was made to the GSM service operator to install the menus via OTA to a specific cellphone SIM card. Once the WML code was lodged with the GSM service operator, the OTA download takes place anytime within a few hours to three to four working days, depending on the load of application downloads. The OTA process takes between two to five minutes. Once completed, the cellphone must be restarted to load the WIG menus under the menu option "Vodata".

3.7.2 Usability Test Results

As the SUS results were scored out of 100, it was decided to use a similar scoring for the numeric scaled responses from the HFT. This provided for a secondary scoring measure that could be compared to the SUS score. As certain human factors aspects such as education level, age, gender and task completion time were not reflected in the HFT score, comparative bar graphs of the average results relative to one human factor were plotted to determine how significant their influence was.

Figure 3.5 shows the comparative results of the average HST and SUS scores for both applications for each type of test. The first point to note is that the HFT and SUS scores are at different levels but produce the same trend, and this relationship is consistent in all tests. As Applications A1 and A2 are the same application being tested on different platforms, it is important to compare the results. It can be seen that the results using the WAC simulator on the PC are lower due to lack of familiarity and the increased complexity for the user and, as expected, the usability results from the cellphone test are comparatively higher. Overall when comparing the current menu (Application B) with the new menu (Application A1 and A2), it can be seen that the current menu is regarded as more usable, however by not more than 10%.

At this stage it is also important to note that the graphical results for the following human factors are not shown for the following reasons:

Education Level

All users were at the same level (tertiary education), except for 3 (high school). However certain user responses reflected a lack of understanding of the questionnaire and to avoid skewing the outcome of the results, they were disregarded in the analysis.⁸ The possible reasons for this were noted as language barriers and education level. Therefore the remaining results could be regarded as a homogenous group with respect to education level.

Age and Gender

Analysis of these human factors resulted in no significant differences between the testing results.

Computer Experience and Cellphone Experience

As shown in the results summary in Appendix B, the average level of computer and cellphone usage experience was very similar and therefore had a negligible effect on the testing results.

English first language

This also had no effect as second language English speakers had a sufficiently high level of language use at a tertiary education level to allow them to complete the test questionnaire with no difficulties.

An interesting observation that came to the fore is associated with learning and retention in the short-term. The following graph is a summary of the time taken to complete a task for Groups A and B testing the new menu (Application A) on the PC and cellphone. Two testing sessions were carried out 30 minutes apart. Figure 3.6 shows that Group A took longer to do the task on the PC than on the cellphone, as the first test was on the PC. Group B shows exactly the same relationship but in the reverse order as they completed their first test on the cellphone.

⁸Please refer to the results of Group C in Table B.2 of Appendix B.

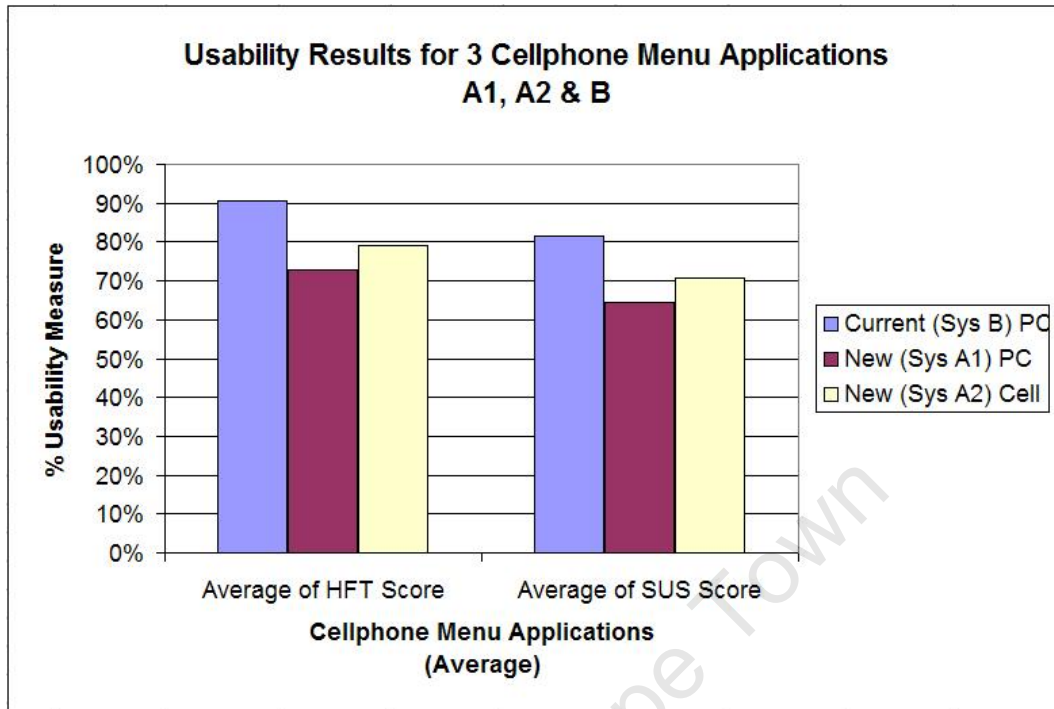


Figure 3.5: Comparative usability test score results for all 3 application tests

This relationship therefore gives insight into task completion time improvements based upon learning and short-term retention. Therefore, further investigation was carried out with respect to the effect on HST and SUS scoring. Figures 3.7 and 3.8 show that in general users that completed the task in under 10 minutes gave the new menu application a higher usability score. It is interesting to note that users that took longer than 10 minutes in both testing sessions using the PC followed by the cellphone rated the usability of the application in the second session very low.

Figures 3.9 and 3.10 show the opposite relationship with Group B carrying out their first test of the new menu on the cellphone followed by the PC. Users that completed the task under 10 minutes gave lower usability scores than those that took longer, possibly due to a reduction in perceived usability from cellphone to PC simulator. Throughout the testing, Group A showed very little variance in scoring with respect to task completion times. Therefore, overall these results indicate a bias in the scoring process depending on which device (PC or cellphone) was used first and how long a task took to complete.

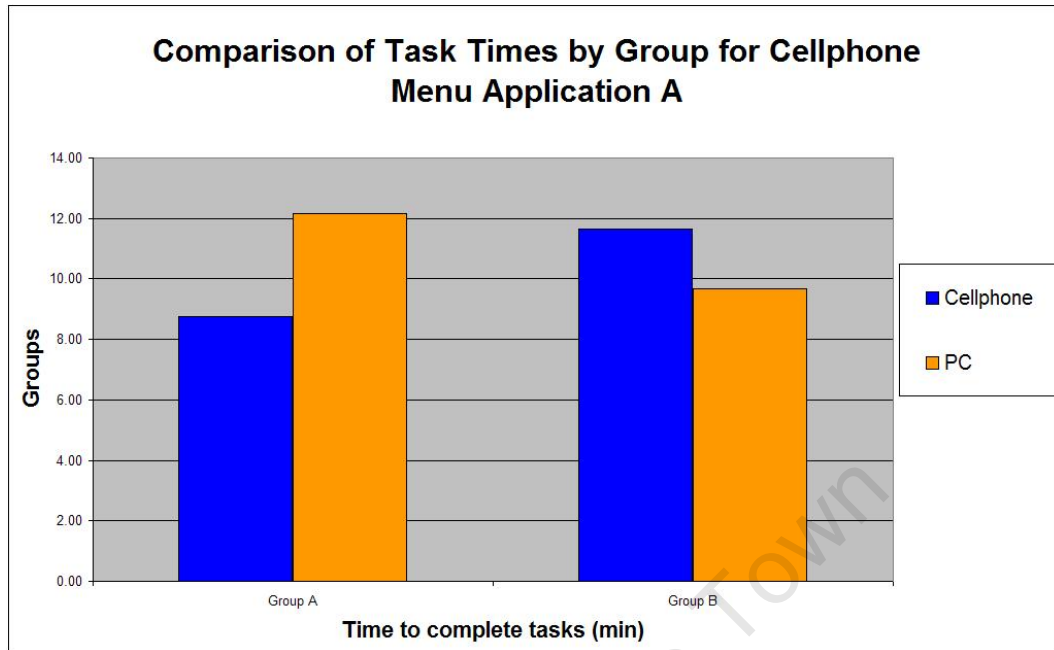


Figure 3.6: Comparison of task times by group for the new menu (Application A)

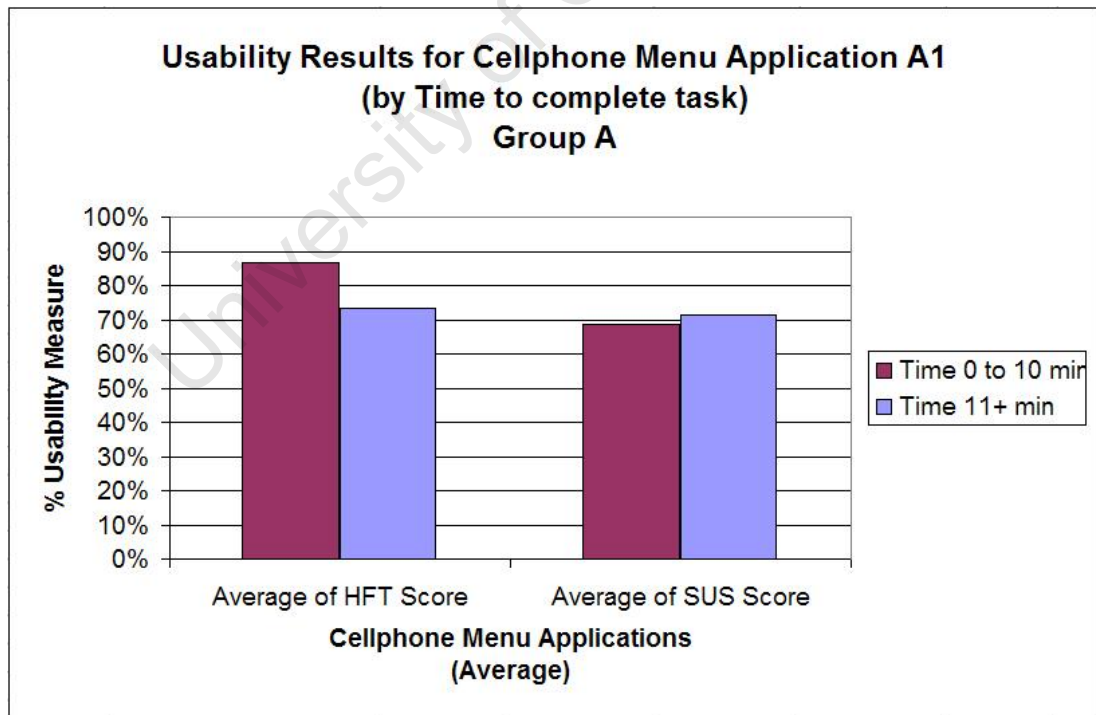


Figure 3.7: Average usability scores for new menu PC test - Group A

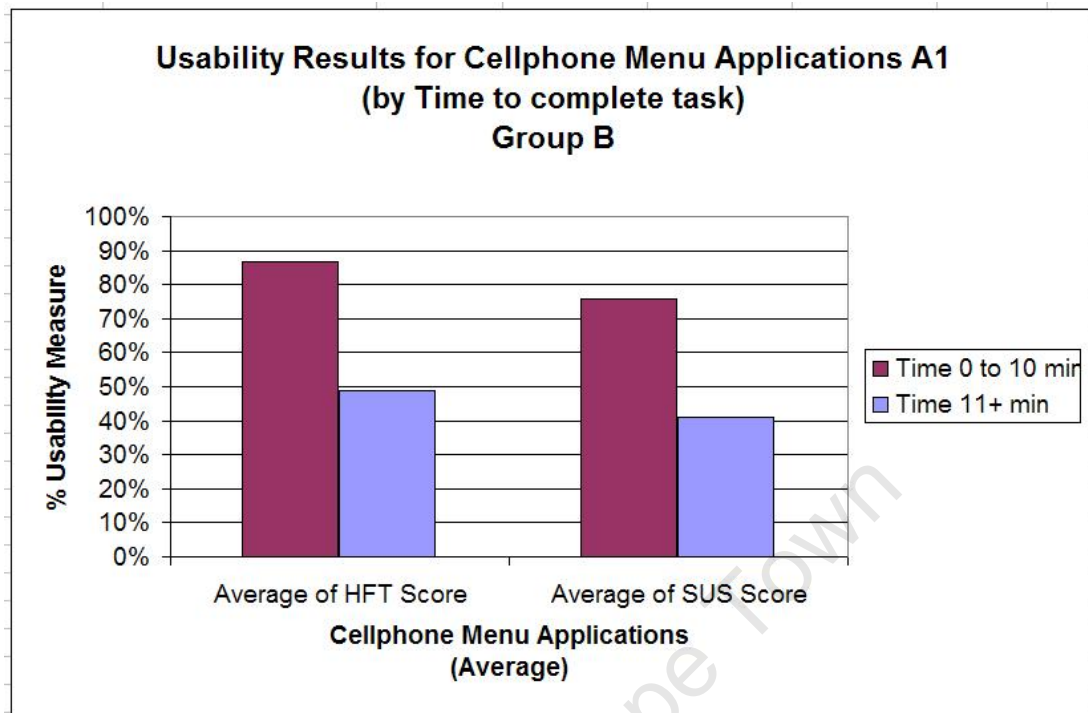


Figure 3.8: Average usability scores for new menu PC test - Group B

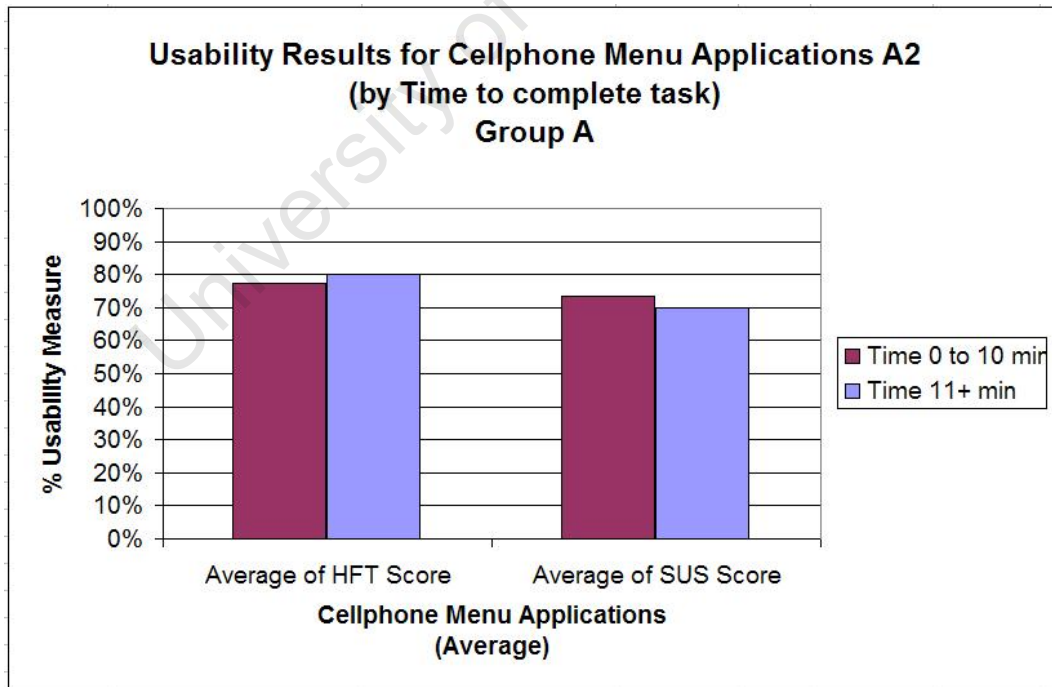


Figure 3.9: Average usability scores for new menu cellphone test - Group A

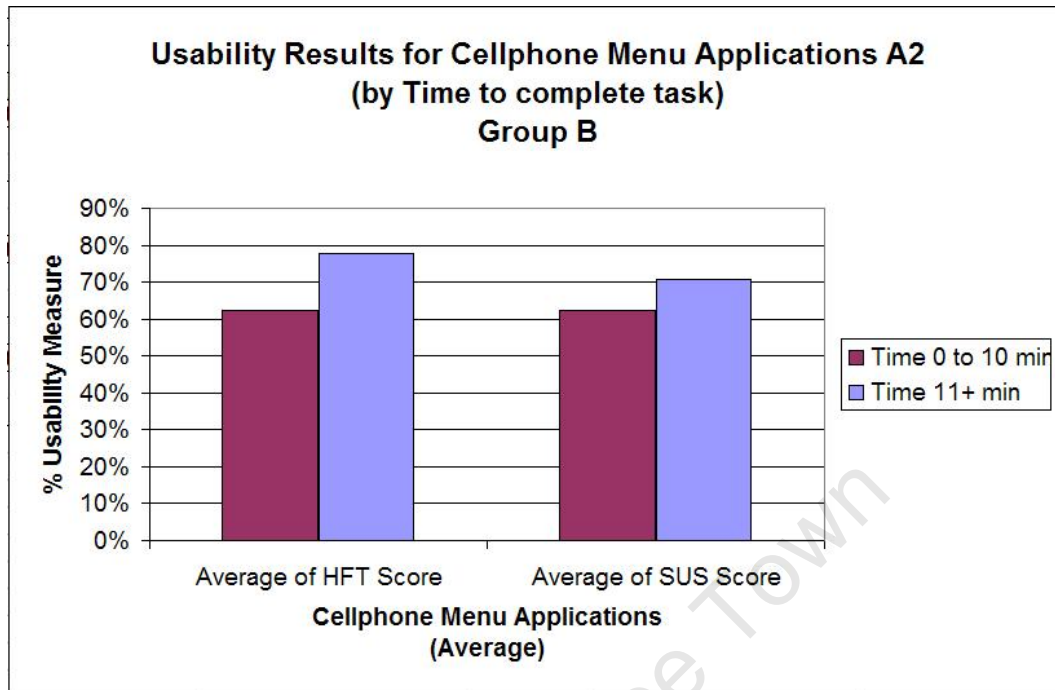


Figure 3.10: Average usability scores for new menu cellphone test - Group B

3.7.3 General Observations and User Feedback

During and after the testing process the users were asked to provide general feedback in the questionnaire and verbally on the testing session for all menu applications and the main points from this are summarised as follows:

- The two green buttons on the WAC simulator were confusing. One green button was used for making calls and the other was used for interaction with the menus.
- Making a mistake meant cancelling out completely and starting all over again which was very frustrating and irritating.
- The new menu application required remembering a number associated with a drug, which was difficult and required regular help from the training chart.
- Generally the collection process was felt to be too repetitive.
- Users were used to their own cellphones and the different location of common buttons on the Nokia 3310 used in the test made the testing process

more difficult.

- In general, the PC WAC simulator was more difficult to use than the cellphone, but provided a useful option to go back one step which does not exist on the cellphones.
- In general users were oblivious of the number of SMSs sent as they did not incur the cost, and the SMS submit option was as simple to use as any of the other menu selections.
- Users were confused that the new application required multiple menus for data collection with fewer SMS submits whilst the older menu application covered all data collection with many SMS submissions.

As the new menu application was tested using actual cellphones linked to an existing database, it was possible to assess the quality of the collected data. The tables of detailed errors can be found in Appendix B and the errors are summarised as follows:

- Data was collected by 15 test users for 2 patients each, creating 30 database records of 17 adherence menu fields and 12 monitor menu fields. Therefore 510 variables were collected under adherence and 260 under monitor, making a total of 870 variables.
- In the adherence menu:
 Only 6 variable errors (1.2% of collected variables) were found and 1 repeat collection error,
 2 of the errors were carried out by one user,
 3 were drug name errors and 3 pill count errors.
- In the monitor menu:
 6 users sent an SMS for each section of data rather just one,
 5 complete patient records were not received (60 variables),
 Only 4 variable errors occurred out of the 200 collected (2% of collected variables),
 2 empty SMSs were received,
 In total there were 6 method errors and 6 data capturing errors.

3.7.4 Results of Comparative SMS Costs

A comparison test was carried out on the number of submits and subsequent SMSs sent for a general patient visit. The sample patient visit card identity number 818 was used for this test.⁹ The total number of SMSs sent using the current menu was 9, but as the *alert* function is only used for emergencies it is not included in the test resulting in a total of 8 SMSs. The comparison results in a 75% cost saving from the new menus and it is summarised in Table 3.2.

<i>Application</i>	<i>Patient No</i>	<i>No of Submits</i>	<i>No of SMSs</i>	<i>Total Peak Cost</i>
B (current menu)	818	8	8	R6.80
A (new menu)	818	2	2	R1.70
Rand Saving				R5.10
% Saving				75%

Table 3.2: Cost comparison of cellphone menu applications

3.7.5 Conclusions

Visiting a user-centred design approach, a participatory design process was carried out that resulted in the development of the cellphone menu applications. Security of WIG data collection was investigated with relevant recommendations put forward in Chapter 9. Difficulties were encountered with regard to the development of the new menu applications based upon user specified requirements due to a lack of standards implementations by both the GSM operator and cellphone handset manufacturers. Finally, a cost saving was successful due to a reduction in the number of SMSs required during data collection.

⁹Sample patient visit cards use in the testing can be found in Appendix B

Chapter 4

SMS DATA SUBMISSION AND DATABASE INTEGRATION

All data collected using cellphone menu applications is transmitted over the GSM network in an SMS format to the database server. A GSM modem attached to the server receives the incoming SMSs using the Kannel software programme. Perl scripts are then used to extract the data from within the SMS and to insert the data into the database. A number of problems in this stage of the data collection process were identified and then solved in order to avoid loss of data. In addition, the new cellphone menu applications were linked into the database.

The existing database was modified to accommodate the new format of data, the new data sets of adherence and socio-economic information, and the decoding of data was moved from the scripting stage to within the database. The existing Perl scripts were modified to accommodate the needs of the new cellphone menu applications. An assessment and investigation into WIG security was also carried out. The chapter ends with an overview of the results from SMS data submission speed tests.

4.1 Documentation of Current Implementation

When a cellphone menu application is used, the final command is a “submit” option. The submit gathers all the data collected and stored in variables in the

WML code, and it sends the data as an SMS to a GSM modem via the WIG server. Each SMS is capable of storing 160 characters of data in a standard format. A maximum of three concatenated SMSs can be used to communicate to the WIG cellphone data. Due to this data capacity limitation, data collected in the menu is in a shortened format in order to increase the efficiency of data collection using fewer characters in an SMS.

Kannel is an OSS program that operates the GSM modem on the server. Menu applications are linked into the Cell-Life database via CGI scripts written in Perl. Kannel uses a keyword trigger specific to each menu application. When the GSM modem receives an SMS, the keyword trigger calls a relevant CGI script via an HTTP request. The CGI script extracts the data from the SMS and expands the data to full format via embedded lookup tables and inserts the data into the database.

As an example, there are 12 ARV drugs used in the system, each with a very long name. Due to the 1K WIG application size limit and the SMS data capacity limit, abbreviations are used for the drugs on the cellphone screen, and numeric values are assigned to each drug. Nevirapine is therefore displayed as NEV but referenced with the numeric value 1. Any drug variable transmitted from the cellphone with this value is re-associated to Nevirapine in the CGI script. Therefore, the order of variables sent from the menu application as well as the shortened format are necessary for the CGI script to align the data correctly.

The GSM modem is connected to the server via an RS232 connection. There are no security threats in the local connection, but the GSM data path of the SMS is not secure or protected. Encrypted GSM communication of the data over WIG is possible, but it is not implemented in the current system. It is believed that the numeric based tagging of transferred data significantly reduces the risk of any data confidentiality issues. Compromised SMS data would be of no value without additional information such as patient ID number association to name and the order and interpretation of the data variables. Access to the WML code of the menu application or the database CGI script would be required for complete interpretation. This coding method provides for a high level of data security due to the non-transparent variable decoding process.

The chosen database is PostgreSQL. PostgreSQL is an open-source object relational database management system (ORDBMS). *Postmaster* is the PostgreSQL

daemon that is the primary target for database connections. The database is used to store all data collected by home-based carers using the cellphones. The database also contains additional information about home-based carers, patients, web users and the pilot site as shown in Figure 4.1.

A dedicated user account is assigned for access and development of the database. When a table is created the number of data fields and their corresponding field types (integer, character) must be considered. Also, as data is inserted into the table one row at a time, a sequence is created to monitor and index the order of the incoming data. Finally, links of corresponding data using a cross-referenced table called a *view* can be used. In the Cell-Life database, separate tables hold information about the home-based carers and their cellphones, as different cellphones may be used by different carers. In order to display the combined information, the relevant sequence index from the cellphone table called the *cellphone_id* is placed in the home-based carer table. The final result is a table *view* combining all the relevant data from the carer table and the cellphone table.

Finally, the new database table *view* (of multiple related tables) that holds the collected data is made available for the web user. This is done by editing the *index_pilot_site.php* used to configure web user access to data.¹

4.2 Problems and Issues Identified

The proposed new cellphone menu applications described in Chapter 3 were developed based upon a range of specified requirements. These changes have affected not only the data transfer process, but the CGI scripting and database. CGI Perl scripts are used to extract data from the SMS and to insert the data into tables in the database.

As described in Chapter 3, three new WIG menu applications have been designed and developed. The menus were developed according to the WML programming reference guide.² As the new range of data collection variables is wide, an alphanumeric variable referencing system has been developed and implemented in

¹A sample web screen shot of this page can be seen in Appendix D.2

²This guide is shown in Appendix A.6.2

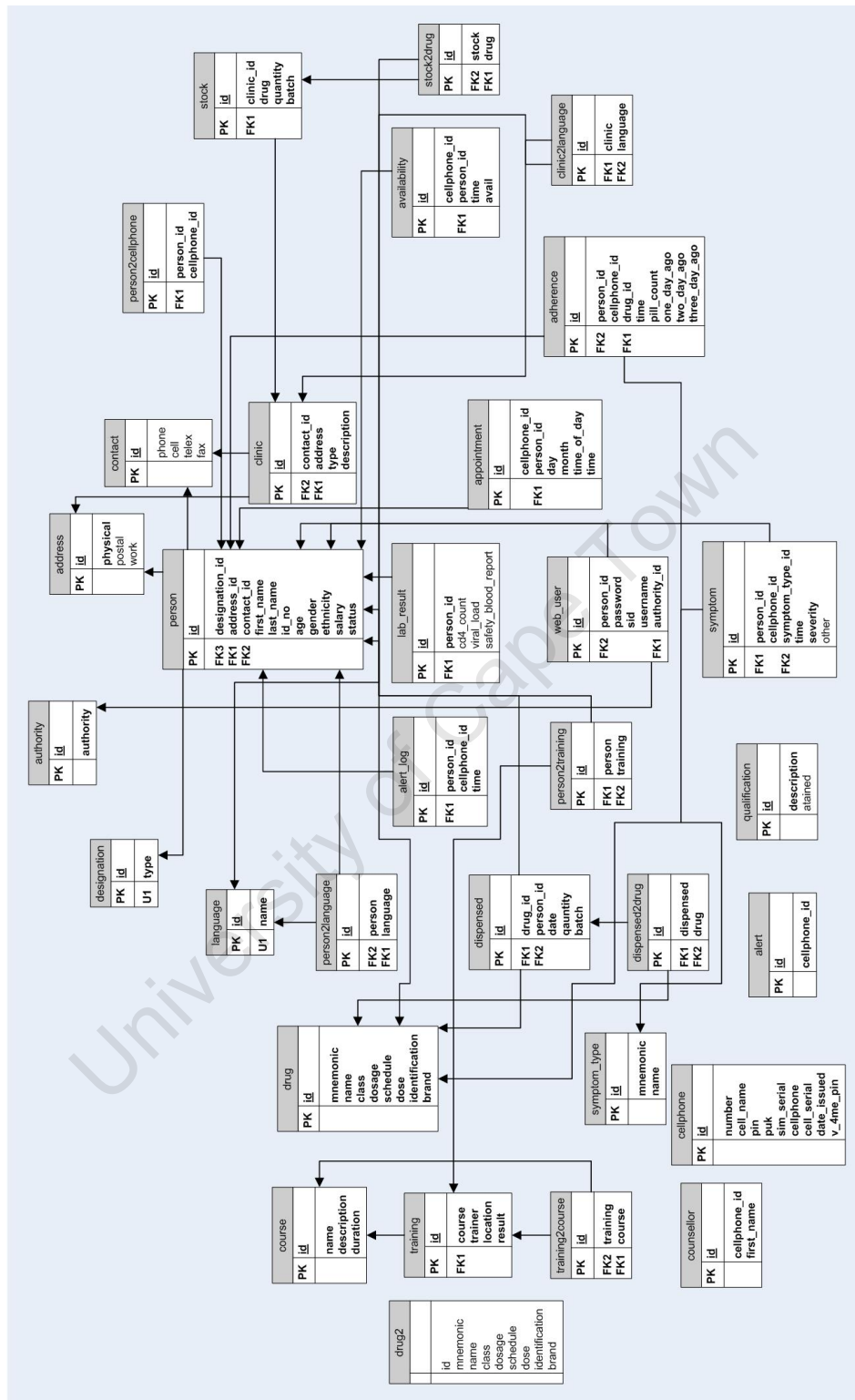


Figure 4.1: The Entity Relationship Database (ERDB) Model Diagram

the new menu applications.

The following is a summary of the problems, issues and required changes that have been identified in the area of SMS data submission and database integration for the three new menu applications:

- An investigation into the SMS data losses is required including the development of a corrective response.
- New/updated CGI scripts were be developed, configured and implemented for each menu application.
- The coding and decoding reference of variables is be carried out as used in the current method to ensure ongoing data security and integrity.
- An investigation with recommendations for improving WIG application security on the handset and during data transfer is to be carried out.
- A database orientated lookup table to decode SMS data variables based upon the alphanumeric referencing is required.
- New database table views must be developed to provide an increased level of cellphone data interpretation for web admin users.

4.3 Quantification of SMS Data Losses and Corrective Measures

SMS data losses occurred and needed to be investigated. The GSM modem in use is the Falcom A2D-1-900/1800. An investigation into this problem found that the Kannel GSM modem software requires two services to run the GSM interface. However, they are required to start up automatically when the system is rebooted and they currently have to be manually started. As the servers are to be based in an inaccessible server room, the server may reboot without the system administrator's knowledge. Data loses can be minimised due to the fact that incoming SMSs are queued by the GSM service provider for up to a 24 hour period. Therefore there is only a 24 hour window for correction of the problem before permanent data loss occurs.

Investigation into the Kannel SMS log files revealed that in a 6 month period, the server was rebooted four times and as a result a total of 25 days of data loss occurred before manual intervention corrected the problem. Over 2003 a total of 2311 SMSs were received by the server. This gives an average daily SMS rate of just over 6 errors. Therefore it is estimated that 158 SMSs were lost during this period as the Kannel services failed to initialise. The reason for the high SMS volume load over the period is due to the high rate of SMSs required in data collection on the current menu.

The corrective measure taken to solve this problem was based on writing a UNIX shell script to automate the startup of Kannel services and bootup. The specific Kannel GSM software services are *bearerbox1.1.6* and *smsbox1.1.6* and they are required to run automatically at start up. On execution they initialise the Kannel GSM modem interface based upon the configuration file *smskannel.conf*.³ The execution of the shell script at server boot time is written and implemented using the *cron* daemon scheduler. The following is the shell script:

```
1 bearerbox-1.1.6 -v 9 /usr/local/etc/smskannel.conf &
2 /bin/sleep 2
3 smsbox-1.1.6 -v 9 /usr/local/etc/smskannel.conf &
```

The script was successfully implemented, starting up the required services when the server is reset or turned on, effectively solving the most critical data loss problem.

Another identified reason for data loss was the configuration and set up of the Kannel software. Each incoming SMS initiated a corresponding CGI script. The call for the CGI script was carried out via HTTP. In the investigation it was found that the HTTP call was set up via the IP address and not the Domain Name (DN). Therefore any IP changes from the university DHCP (Dynamic Host Configuration Protocol) server on the network resulted in a breakdown in the HTTP call. However, as long as the SMS arrives, a log is created by Kannel providing a permanent record of collected data. If the CGI script fails the data is not inserted into the database but it is not lost. A manual search for and correction of such errors is therefore possible. It was found that over a 4 month period that the IP address changed twice resulting in 34 SMSs being received by

³A sample of the *smskannel.conf* file can be found in Appendix A.8

the GSM modem but not correctly inserted into the database.

The corrective measure chosen was based upon the most effective choice out of three options of configuring the HTTP call for the CGI scripts via:

1. IP address
2. DN
3. *localhost*

A DN is constant even with a changing IP address. It was found that all three methods worked effectively, however the DN method resulted in unexpected errors and problems due to the DNS set up of the university network. As the IP address can be changed unexpectedly, the best alternative was to use the *localhost*. The biggest advantage of the *localhost* was that it did not rely on the external network configuration. In the event of a network failure, SMSs could come through via the GSM modem and be inserted into the database irrespective of the state of the network. This option drastically reduces the risk of any data losses from this specific type of problem. As there is an electronic record of the log files, past CGI script errors were possible to manually correct and reinsert into the database.

4.4 Specification and Documentation of SMS Data Submission Modifications

Changes to the cellphone menu applications affect the Cell-Life system and new or updated CGI scripts and database tables are required. Data collected on the cellphones is in a keyword format. Home-based carer cellphone numbers have to be registered with the Cell-Life system for use. This is done by the creation of a home-based carer table that contains all the relevant information about the carer including their cellphone number. When the incoming SMS initiates a CGI script, the first step carried out by the script is validation of the sender. If the sender is validated, the SMS data is separated out, stored into temporary CGI variables which are then inserted into the corresponding database table using

SQL commands and variable substitution. A sender validation failure results in an SMS to the sender stating this.

The updates required to the CGI Perl scripts are minor due to the fact that the CGI scripts are no longer used for variable substitution. However, the separation of incoming SMS data values and the assignment of temporary Perl variables is still an important step in the scripting process. Depending on the manner in which a WIG menu application is programmed, the sequence of the variables within the SMS has to be matched correctly in the CGI script. An example of this relationship can be seen when comparing line 178 of the WML code (Cell-Life Monitor Menu (G2) V1.4) shown in Appendix A.6.1 and line 57 of the corresponding CGI Perl script shown in Appendix A.1. There is a similar procedure used in the CGI script when the SQL command is called to insert the relevant data into the database table. The inserted data sequence must match the corresponding data field and data field type (integer, character) within the table as shown in lines 109 to 113, or else the insert will fail.

Throughout the entire development process, the naming convention used for data variables in the WML code (WIG menu application), CGI script (database insertion) and SQL database tables is kept consistent. This is especially important when dealing with multiple menus, each with many different data variables. The update of the CGI script is directly connected to the database, for correct translation from SMS format to SQL insertion into the database table. Then a test SMS can be carried out from a cellphone WIG application. The CGI script can also be executed for testing purposes via the command shell or by making HTTP requests via a web browser. The incoming SMS is recorded in the *smsbox.access.log* file. At this stage, Kannel is not able to initialise the script as the keyword is not yet linked as a service. The data contained in the SMS is shown in the log file. The relevant CGI script can be manually executed at the command within the shell. This allows any errors in the CGI script, the SMS data format, the database tables and database table user access to be analysed. If errors are found, the specific problem area can be identified and corrected from the resulting error feedback in the shell. The following is an example of a successful manual command prompt CGI script insert:

‘G2’ is not yet configured in Kannel to link to a CGI Perl script.

The specific updates made to the CGI scripts are summarised as follows:

- The current CGI script was taken and scaled down to remove the data translation process.
- The same SMS message “carving” process of associating variables from the SMS to internal CGI Perl variables by sequence was carried out for each menu application.
- The functionality to test the validity of the sender was kept, based upon an SQL query to the counsellor table in the database for sender verification.
- All the CGI scripts were configured to insert data to the same existing database, requiring the same username and password access to the SQL database.
- Each script was configured to be initiated by a menu application unique trigger keyword.
- Lastly, the incoming data from the SMS in its raw alphanumeric and numeric format was inserted into a new table such as *g1_app_data* (data from the adherence menu application).

4.4.1 WIG Security

In the process of investigating WIG security, a technical advisory meeting on WIG technology was held with A Maden of Fundamo in July 2003. Specific to WIG security the following recommendations were developed based upon input from A Maden:

- Set up an HTTP network connection between the GSM service provider’s WIG server and the Cell-Life server via: Leased Line, Internet SSL connection or Frame Relays to allow secure point to point connections.
- Use a secure HTTP connected data path for the incoming SMS, which would not only increase security of data but it would significantly increase

the data transmission speed, avoiding the current queueing method common with SMS. This is due to the communication path being based upon a quick point to point HTTP connection with realtime data transfer. CGI scripts could be used to communicate directly with the WIG server to process incoming data, and dynamic WML screens could be called by the cellphone user from the Cell-Life server, due to the increased transmission rate.

- Implement security on the cellphone with the use of a PIN (Personal Identity Number) for the cellphone user and SSL encryption of the data sent from the cellphone WIG menu application. The encrypted data path of the SMS would be processed by a security verification server next to the WIG server. A HSM (High Security Module) would be needed at the data entry point of the Cell-Life server to decrypt the incoming secure SMS data.

Security and encryption of the SMS data path from the cellphone handset to the Cell-Life database can only be implemented once a network connection is established from the WIG server to the Cell-Life server. This would require a specific level of WIG application stability, standardisation and a wider spread of cellphone user implementation for the current WIG applications to move from the “test” server to the “live” server. The above points are summarised as recommendations in Chapter 9.

4.5 Specification and Documentation of Database Modifications

In order to link the new WIG menu applications to the database, three new CGI scripts were written for database data insertion. The trigger keywords that initiated the scripts were configured in the *smkannel.conf* configuration file. Database tables with relevant lookup tables, sequences and views were developed. As the amount of cellphone data collected had increased significantly from the previous menu, much care had to be taken in these developments. Dealing with more than twenty different variables and multiple tables (cellphone data, lookup data, carer data) results in complex SQL statements. An example of this is

shown below with the creation of a table in SQL *view* for the *Monitor Menu* cellphone data:⁵

```
1 CREATE VIEW "vw_g2_app_data" as SELECT a.id, (a."time")::abstime AS
    report_time, a.person_id AS patient_number, co.first_name AS
    counsellor_name, ce.number AS counsellor_phone, d1.name AS drug1, a.d1_pl
    AS drug1_pills_left, a.d1_1dy AS drug1_doses_1day, a.d1_2dy AS
    drug1_doses_2day, a.d1_3dy AS drug1_doses_3day, d1.name AS drug2, a.d2_pl
    AS drug2_pills_left, a.d2_1dy AS drug2_doses_1day, a.d2_2dy AS
    drug2_doses_2day, a.d2_3dy AS drug2_doses_3day, d1.name AS drug3, a.d3_pl
    AS drug3_pills_left, a.d3_1dy AS drug3_doses_1day, a.d3_2dy AS
    drug3_doses_2day, a.d3_3dy AS drug3_doses_3day, a.missed_dose, a.lost, a.
    damage, a.pregnant, a.se_rash AS side_eff_rash, a.se_abd AS
    side_eff_adb_pain, a.se_para AS side_eff_paraesthesia FROM (((g1_app_data
    a JOIN cellphone ce ON ((a.cellphone_id = ce.id))) JOIN drug d1 ON ((a.
    d1 = d1.id))) LEFT JOIN counsellor co ON ((ce.id = co.cellphone_id)));
```

An alphanumeric reference guide was developed to ease the linkage and the integration of cellphone data into the database. Instead of using the CGI script to combine the shortened format cellphone data, the reference guide was developed to align all alphanumeric variables with all possible data collection variables. This allows the development of a single lookup table within the database that is used by multiple different menu applications. For instance, the data collected using the three new cellphone menus would be stored directly into tables in the database using CGI scripts. The final user view of this data would be based upon the combination of the raw cellphone data with the data stored in the lookup table.

Figure 4.2 is a database diagram showing all the tables in the database, the entity relationships and the views made available over the web application interface. The new tables are coloured blue for differentiation with other existing tables used in the final *view* coloured in yellow.

As an example: when collecting data that requires the selection of a month, the options on the cellphone menu are displayed as the months (Jan, Feb,...Dec). When the month is selected, the variable is set with any of the following:

‘m01’, ‘m02’,... ‘m12’ equivalent to (Jan, Feb,... Dec)

By looking at the variable it is possible to tell what the variable is referencing. This option can only be used with predefined variables. If data such as the

⁵Appendix A.3 shows examples of how tables, sequences and views are created, as well as tested with a data row insertion.

number of pills taken by a patient over the last week is collected, the input would be purely a numeric data value.

4.6 Specification and Design of Test Data and Test Procedures

There are three stages to the data collection process that are susceptible to errors or faults that could cause the loss of data or failure to extract data from an SMS and correctly insert into the database. These are:

- the GSM modem operated by Kannel,
- the CGI Perl scripts that extract SMS data and insert into the database,
- and lastly the database tables.

Therefore, if configured correctly, the entire system will be able to function as required. Data throughput loads have an impact on the operation of the system, however it is noted by Kannel that their testing has shown delays in the SMSC and not with the Kannel software which has successfully managed multiple connections summing a pipeline with 400 messages per second [30]. As the incoming SMS connection to Kannel is via a GSM modem, the GSM operator queues multiple SMSs sent to a single user on the network for up to a number of days. At the current transaction rate of approximately 6 SMS data transactions per day, the database requires no more than 10 field insertions per transaction. Therefore it is important to note that the maximum transaction capability of the database is rated at the 100s of transactions per second level and it is therefore not a concern at this stage to system stability [42].

Due to the rate limiting step of the data collection process being identified as the incoming SMSs, a test was carried out at this stage. In order to carry out this test, cellphones with the new cellphone menu loaded were used to send individual messages as well as bulk group messages. The GSM network SMS transfer time, from submission at the cellphone to being received, logged and inserted into the database, was timed. The cellphone group size test of concurrent submissions was carried out in units of 6, 12 and 18 data collection SMSs.

The testing process of a completed menu also includes the data communication path and insertion into the database. The implementation of the database insertion process was described in Section 4.5. However, the testing of the data submit function is described here. In order to be sure that a newly developed menu's data is received by the server, a menu on the cellphone is completed with data inputs and then the submitted. To confirm the correct set up of the database and lookup tables, data collection was carried out using all three new cellphone menu applications with different datasets. Any errors in the lookup table were immediately noted and corrected. This process was carried out in an iterative manner until every variable collected with the cellphone menu applications was correct.

4.7 Test Results

Figure 4.3 is the summary output of the SMS transfer times from the cellphone handsets to the database.⁶

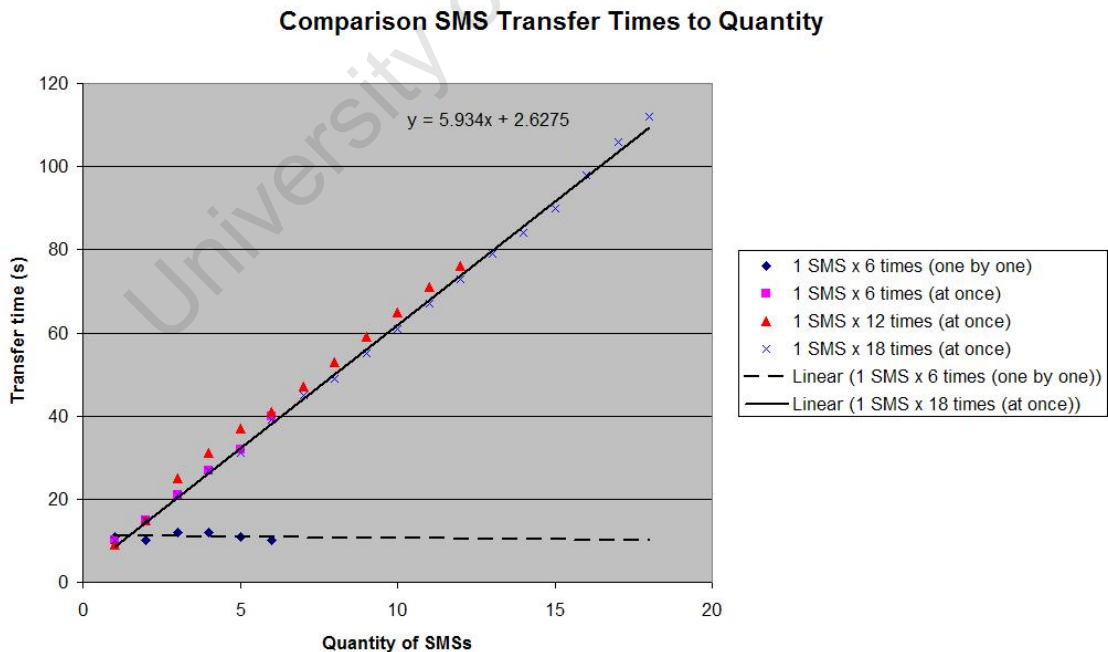


Figure 4.3: Comparison of SMS transfer times relative to quantity load

⁶The table of results for the SMS speed tests can be found in Appendix B

The first data series is the transfer times for a total of 6 individual and independent SMSs. It can be seen that individual SMSs take an average of about 10 seconds to be communicated. The second, third and fourth data series are for concurrent group SMS submissions from 6, 12 and 18 cellphones menus at once. It can be clearly seen that, although the SMSs were initiated at the same time, there is a deliberate queuing process being applied by the GSM network operator resulting in the linear representation of the transfer times. It can be seen that 10 SMSs take approximately 60 seconds to transfer and that as this relationship is linear, the trend line equation ($y = 5.934x + 2.6275$) can be used to estimate how long it would take for larger volumes of SMSs. Since this process is regulated by the GSM, there is not much performance influence on the operation and effectiveness of the data collection process. It was found that over the 18 SMSs, the operator on average delayed each message by 5.7 seconds and therefore in the event of a large cellphone data collection load, this would be the maximum rate limiting point of the process, which, at 10 transactions per minute, is still well within the capability of the database.

Chapter 5

WEB APPLICATIONS AND OFFLINE DEMONSTRATION SITE

ART site management staff were provided with remote access to the data collected using the cellphone menu applications over the Internet through web applications. This chapter covers the development of the web applications to include remote access to the data collected with the new cellphone menu applications. The development of the web applications was carried out using the existing PHP code of the prototype system as a base. In addition, new functionality based upon user requirements was developed and implemented. Examples of this include a web-based SMS application, incoming SMS reporting and the development of an offline demonstration version of the web applications. Minor modifications to the configuration of the web site were also carried out to enable Internet search engines to register the web site. Usability testing of the current and new web applications was carried out and the chapter ends with a summary of the usability findings.

5.1 User Analysis

As identified in the user analysis carried out in Chapter 3, the second user group consists of the medical and administrative staff of a supported ART site and

they are called **web users**. In the current cellphone data collection method, the administration or medical staff of an ART site are given remote access to the database via a web site using web applications. At present there is only one web user level for ART staff users.

A second web user group consists of users interested in learning more about Cell-Life. Such users could be fellow researchers, staff of existing or potential ART sites, university students and funders, to name a few. The Internet provides wide scale access to information about the Cell-Life research group. These users are described as **web visitors** in this document. It is important to note that input and feedback from ART staff users has been carried out via the pilot site implementation. However, the second group of general online users are no accessible for such input and feedback.

5.2 Requirements Analysis

Based upon meetings and interviews with two of the ART site web users and functionality updates due to the three new cellphone menu applications, the following is a list of requirements for the web application:

- Updates are required to correctly provide web users online access to data from the new menu applications.
- Cellphone user information currently not viewable to web users is required.
- Web users requested the functionality to be able to provide web-based SMS responses to cellphone users, after checking collected data and for general communication feedback.
- A reporting system to show how many SMSs a cellphone user submitted in a period of time (monthly) for performance assessment and SMS cost monitoring.
- A report logging process of each successful web user login to the online database for feedback to the ART site.
- An offline web site demonstration version of the web applications and web user access functionality for demonstration purposes in peri-urban and rural

locations. This is required due to limited Internet access in these locations and to aid in the participatory design process.

- A new web user level must be created to allow web visitors access to the system for online demonstration purposes.
- The Cell-Life web site is not being recorded by search engines such as Google and this needs to be investigated and corrected.
- Carry out visual improvements in line with HCI theory, including aspects such as system identification and updating the colour scheme on the welcome page.

5.3 Task Analysis

The task analysis stage of the development process is taking the list of requirements and converting these into specific system functions either of an automatic or of a manual nature. Table 5.1 is a summary of the user specific tasks followed by the system functionality.

5.4 Design

5.4.1 Web User Updates

The web-based interface is based upon PHP scripting.¹ PHP scripting is used with HTML to access the database. The database not only houses data collected by cellphone users, but also information about the users, the patients, the web users and the pilot site. HTML can be embedded within PHP making PHP an effective method of providing access to the database. In this application PHP is only used for querying and retrieving data from the database. All web-based access to the database takes place through a PHP login page. Web user details such as the username and password are stored in a table within the database.

¹Sample PHP code of the index web interface page can be seen in Appendix A.2

Tasks	System Functionality
<i>Provide a web user view of the new dataset collection tables in the database from the new menu applications</i>	Link the web interface with the updated database tables housing the new menu data
<i>Provide a web user view of the cellphone user information (names and cellphone numbers)</i>	Link the web interface with the specific home-based carer database tables
<i>Provide the web user access with an on-line web to SMS functionality</i>	Investigate and implement a system based SMS feedback link to cellphone users via the web site
<i>Provide the web user with SMS count and cost reports specific to each cellphone user on a monthly basis</i>	Develop a system reporting method to count SMSs and calculate the SMS costs and make this available to web users
<i>Provide the ART site with a report on the number of online database access logins by web users</i>	Develop a sytem reporting method to record web user logins and make this available to the ART site
<i>Provide the ART site staff with an offline version of the Cell-Life web site and web user applications</i>	Develop a static offline version of the system reflecting web user functionality
<i>Create a guest web user login for online demonstration purposes</i>	Investigate and set up a guest web user login to view test demonstration data that does not compromise access to real site information
<i>Provide web visitors and web users with the opportunity to find the Cell-Life web-site through online search engines</i>	Investigate and correct the online search engine registration and ranking problem
<i>The following visual improvements to the web interface are requested: Cell-Life system identification, web user login information and which ART site data is being viewed, and use of colour to differentiate data groups</i>	Make the visual improvements to the web user interface as specified in the from web users

Table 5.1: Task analysis summary - web applications and offline demonstration site

Upon login, the PHP script queries the database and compares the web user's username and password in order to authenticate access.

In order to link and update the web user interface with the new cellphone menu application data, the PHP code needs to be updated accordingly. As the previous data arrived specific to five different data groups, a menu on the left hand side of the browser listed the five data groups for data access. As there are now three new menu applications, the design would involve replacing the menu options on the left with the three new data groups *adherence*, *monitor* and *social* data. In order to give web users access to the current and older datasets, the old menu options are kept in the left menu column under a new heading labeled *Old Menus*. In order to give access to the cellphone user information, the method used in querying cellphone data is to be employed linking the web interface to the relevant cellphone user database tables.

From a visual improvement point of view, the design will include permanent information in the interface about the system identification, web user name and current ART site location, as well as an update of the colour of menu options in the interface. To create a system identification, the Cell-Life logo will be placed at the top left corner of the interface. To provide the web user with current location and web user login details, the top right hand corner of the interface will be used. Design decisions specific to updating the menu choices by colour are as follows:

- all menu headings are to coloured blue,
- all menu options are to remain in black,
- all new functionality menu options including the *logoff* option are to be labeled red.

Inline with HIC theory black was chosen as it is based upon the need to keep consistent with the current interface. Blue separates headings from menu option choices, and red, being associated with a sense of importance and urgency, is connected to attracting the web users to noticing and using the new functionality.

In order to understand why the Cell-Life web site was not being registered and listed by online search engines an investigation was carried out. In this investigation it was found that an online domain management web site was used for

the domain registrations. Due to university limitations with respect to DNS (Domain Name Services) configurations outside of the university domain, it is not possible to host DNS records for non-university domain servers. Therefore, only a local university specific domain could be affiliated with the server being `http://celllife.eng.uct.ac.za`. This domain name is viewable on the wider Internet but being within the university LAN, not viewable by search engines such as Google. The content of the Cell-Life domain (`www.cell-life.org`) is made available from the university server within a redirected framed HTML page making this process fairly transparent to web users and web visitors.

Therefore, a possible method of solving this problem would be to host the Cell-Life server at a commercial Internet Service Provider (ISP) datacentre, moving the ownership of the domain names to the ISP and associating them with the server. It is also possible to register and notify the details of the current web site directly with a search engine like Google, but due to the current framed web content, verification of the server and content is not possible as the framed content is from a different server, making such a registration and search engine listing is impossible.

Guest login access is possible if a completely separate instance of the existing system is set up and made accessible on the web site. A single guest user account can be created and a short range of falsified demonstration data must be inserted into the cellphone data collection tables. To ensure data security and integrity, an entirely separate and new database must be created, with different user access privileges to the live system.

5.4.2 New Functionality

Web-based SMS

There are a number of potential methods available to set up an outgoing web-based SMS service for web users. The first would be to use the existing set up sending SMSs via the GSM modem. This would require continuous monitoring of the prepaid cellphone user SIM card in the GSM modem, as outgoing SMSs would be billed to the airtime balance of the GSM modem. Therefore, the airtime balance would need to be monitored via a script, using the Kannel interface, in

order to generate notifications to recharge as airtime runs low. In addition, the outgoing SMSs would be billed at the standard prepaid peak and offpeak SMS rates with no opportunity for bulk discounted pricing.

A second option would be via an existing online bulk GSM SMS operator. The method would involve registering an account with one of the GSM WASPs (Wireless Application Service Providers). Once an account is created, prepaid credit for SMSs need to be purchased. It is then possible to set up network initiated HTTP requests through the account', to submit and send SMSs to cellphone users.

A third and final possible method is via the GSM service providers web site. The quickest and easiest method is based upon a free web-based SMS service offered by the GSM service provider to cellphone users on the same network. All the cellphone users have been set up on the same network and therefore this option is a viable one in the short-term.

Due to ease and the low cost of the second option, this was chosen as the primary design method followed by the development of the GSM modem version as a back up alternative. The WASP option was possible but would require the greatest amount of development time and it would be useful in the long-term when a greater volume of SMSs needs to be sent. At present the current pilot site implementation is supporting less than ten cellphone users.

Reporting - Monitoring and Logs

There are two types of reports required. The first is the monthly SMS total count and the total cost of cellphone users. The second is to record the web user login activity and report this on a monthly basis to the ART site.

Many FreeBSD programs and services keep logs of all transactions and events mainly to help with debugging errors. These logs can then be used to isolate, locate and identify problems with certain services. For example *httpd* is the HTTP daemon that runs the Apache web server. All HTTP requests to the server are logged in the file *httpd-log*, as well as any errors in the file *httpd-error-log*.² In order to provide a record of successful web user logins to the web

²Samples of the Kannel and HTTPD logs can be see in Appendix A.9

interface, it was decided that email would be an effective design option. A shell script is a possible option, but it would require the communication of this report directly to the ART site staff rather than via a web application. It could be possible to keep a text file log of all successful web user logins and then provide a separate level of user access to view these. However, the increased complexity of such a development is regarded as beyond the scope of the basic requirement. The final design choice therefore is to initiate an email report to a mailing list of the the relevant management staff.

5.4.3 Offline Demonstration Web Site

An offline version of the website is required for demonstration purposes, such as when demonstrating the Cell-Life system when there is no Internet access. The offline version must include access to the pilot site web login, to demonstrate access to collected data and other services, such as outward SMS and SMS log reports. Another factor is the need to keep sensitive HIV patient data confidential.

The challenge in attempting to create an offline version of the website is that the entire system relies upon a number of software components that are not available for a conventional MS Windows desktop PC environment. At present (June 2003) there is no Windows version of the database. It is possible to implement PHP on a desktop PC but it would need to be installed and configured on every computer used for demonstration purposes. However, it is possible for HTML files to be accessible in an offline environment, provided that the content served in the HTML files is available in a local folder. Web browsers such as Internet Explorer and Mozilla are capable of displaying offline HTML pages. Therefore, the design of the offline demonstration web site is to built in HTML. In the event of not being able to show realtime live data access due to the database and scripting offline limitations, freeze frame screen shots can be taken for illustrative purposes and embedded into the HTML offline pages.

5.5 Documentation of Implementation

5.5.1 Web User Updates

Minor updates to the PHP files that access the database via the web interface were carried out. Each menu option in the interface links to a sub-action that initiates an SQL query to the relevant database table view as described in Section 4.5. The same sub-action creates a table layout view of the requested data in HTML for the web user. Through the programming of this method it is possible to order and limit the amount of data viewable in the web browser.³ To provide access to the cellphone user data, first a web orientated view combining the cellphone and counsellor database tables is created. This information includes data such as the cellphone user's cellphone number, serial number, PIN and date of cellphone issue.⁴ Then in the same manner as described above, the PHP code is updated to link and view the cellphone user data.

The visual changes to the web interface were carried out through standard HTML updates in the PHP script. The relevant colour changes and logo placement were carried out in standard HTML. In order to provide the logged in user with information specific to their login and location, amendments were made to the HTML table border placing the required information in the top right hand corner. When the login process takes place, an SQL query is made to the database where web user details are held. The username is transferred to a PHP variable for authentication against the username entered at the web interface login page. Therefore, with the variable existing in PHP, a simple screen display command in the correct location places the web user name in the right corner of the screen. As the login page is custom designed for the specific site, it is possible to place the ART site name next to the web user name.

Due to the current university based server location and the costs associated with moving the server to an ISP, the registration and listing of the Cell-Life web site on international search engines is not currently possible. However, the outcome of the investigation is summarised as a recommendation in Chapter 9.

A limited number of web users are implemented within the Cell-Life system.

³A sample of the amended PHP code can be found in Appendix A.2

⁴Sample screen shots of the web interface can be seen in Appendix D.2

Additional web users are required including a guest user with limited data access. The implementation of additional web users is carried out by making updates to the *web_user* table in the database. The user level access to the system is also set from within the same table. This allows different user access levels to data within the database. For instance the following three user levels are listed in order of authority from the highest to the lowest:

- Cell-Life development and administration
- Pilot site administration
- Guest

In order to implement a guest user, further alterations are made to the PHP login file to limit the specific functionality allowed to a guest user. Also, the data the guest user accesses for demonstration purposes is from a separate newly created instance of the database with specially created tables, containing false, non-sensitive data. The guest user account is developed to permit guest users limited access to features of the system. The data queried by a guest user holds falsified data.

5.5.2 New Functionality

Web-based SMS

An additional component that is included in the web interface for short-term usage is framed access to the free GSM service provider site. A summary view of all cellphone user details, such as cellphone numbers, is placed below the framed webpage. This allows web users to quickly and easily respond to home-based carers through the web interface at no cost. However, it is anticipated that this feature would not remain cost free in the long-term, as it is being used to encourage prototype testing of a beta version by cellphone users.

Two options via the GSM modem are available for implementation to enable a web-based SMS service. The first is an HTML version developed to execute a built-in CGI script for SMS sending. In addition, a PHP version web page from Kannel is available that uses the same process of calling the CGI script but

employs a greater amount of user functionality. Due to the increased functionality, the Kannel version is implemented after having carried out a comparative test with the author's developed HTML version.⁵ The reason for this is that in the long term, the list of SMS cellphone numbers should be queried from the database, which the PHP code is capable of, and it should not be manually coded into HTML. HTML cannot be used to access the database as it is not a scripting language but a language for displaying web content. A pilot site administration staff member is now provided with access to cellphone collected data via the web interface. The web-based SMS functionality provides the ability to immediately send a return SMS from the web login to the cellphone user.

Reporting - Monitoring and Logs

A summary log of all incoming SMSs is required to monitor cellphone user data collected. A log of web user logins is also required to monitor and keep track of all successful web accesses to the database.

As a log of every SMS transaction is kept by Kannel, a structured query of this log file based upon date, time or cellphone number results in the generation of SMS log summaries. Shell scripts are written in FreeBSD to query the relevant log files and create SMS logs as text files. These text files are then easily made accessible to the web user as SMS reports using HTML. Scripts are written to provide reports of the SMS totals received by the Cell-Life system, and the total SMSs sent by cellphone users based upon pilot site totals and month totals. Once the shell scripts are written, the process is automated by using the *cron* daemon which executes scheduled commands. The scripts are scheduled to run every twelve hours, updating the SMS reports available to the web user.⁶ The following is a summary of total SMSs received by the server from the Gugulethu pilot site over the January to August 2004 period (taken from the developed and implemented SMS Report service):

⁵The screen shot of the HTML page can be seen in Appendix D.2 and the code in Appendix A.4

⁶The shell script code can be found in Appendix A.5

```
1  CELLLIFE SYSTEM (GUGULETHU)
2  -----
3
4  SMS TOTALS: 2004
5  -----
6  Jan:
7      111
8  Feb:
9      73
10 Mar:
11     107
12 Apr:
13     275
14 May:
15     407
16 Jun:
17     402
18 Jul:
19     450
20 Aug:
21     481
```

In order to create a log of all successful web logins to the Cell-Life system, a method based upon email generation is used. The reason for this is to investigate the possibility of confirming logins to the system by sending an automated email to the ART site management. This provides site management with the date, time and frequency of web user activity as each web user has a unique username and password. Simple mail filtering at the receiver's side and monitoring of the outward emails in a log file could provide a permanent record of all web logins to the system. A modification of the PHP login file (the point of access to the database) using the standard UNIX *sendmail* agent enabled the monitoring of all web login access to be implemented. *Sendmail* is an electronic mail transport agent [18]. *Mail* is the PHP command that invokes *sendmail*. The command line added to the PHP login file is:

```
1  mail("abc@xyZ.com", "Cell-Life Server - Gugulethu Clinic - Accessed by
    $UserID", "Cell-Life Server - Gugulethu Clinic - Accessed by $UserID");
```

5.5.3 Offline Demonstration Web Site

An offline demonstration website was developed in HTML using web screenshot images of the online pages. The offline version was implemented to match the online version as closely as possible. As of July 2004 the Cell-Life website

(www.cell-life.org) was re-launched, and therefore the offline version of the website was based upon the old website. However, the new website changes are purely visual and the webpages relevant to the web user login access are still the same. The offline demonstration website can be found on the attached CD-Rom located in Appendix E.1.

5.6 Usability Testing

The process described to carry out usability testing on the cellphone menu applications in Section 3.7.2 is repeated for the web applications. Minor changes were made to the HFT questionnaire and the SUS was used.

Three web applications were tested:

- current (System C)
- new (System D)
- demo (System E)

One of the differences in this testing process is the task specification summarised in Table 5.2.

		<i>Current</i>	<i>New</i>	<i>Demo</i>
No.	Tasks	(Sys C)	(Sys D)	(Sys E)
1.	Log into the web application	X	X	X
2.	View adherence data	X	X	X
3.	Sort data by patient no.	X	X	-
4.	View SMS report - Gugs June 05	-	X	X
5.	Send a test SMS to instructor	-	X	-
6.	Logout of the web application	X	X	X

Table 5.2: Summary of the usability test tasks for the 3 web applications

Figure 5.1 is a comparison of the average HFT and SUS scores for all the web applications. Once again the HST and SUS score level differs, but the trend between both tests is the same. An interesting observation is that although the

functionality of the new application is much higher than the current web application, the usability of the new application has not reduced much in comparison. For both the HFT and SUS, the difference in usability is no more than 5%. As expected with the demo application which has the least functionality and is used purely for demonstrative purposes, the usability is significantly lower than for the first two.

Figure 5.2 shows that the older age group (over 25 years) were slightly more critical, resulting in lower usability scores on two of the three web applications. Figures 5.3 and 5.4 confirm that gender and English first language are not significant factors in determining the usability scores. Figures 5.5 and 5.6 show that neither training time, nor task completion time are significant but that the HFT holds downward bias on usability scoring for the longer time periods.

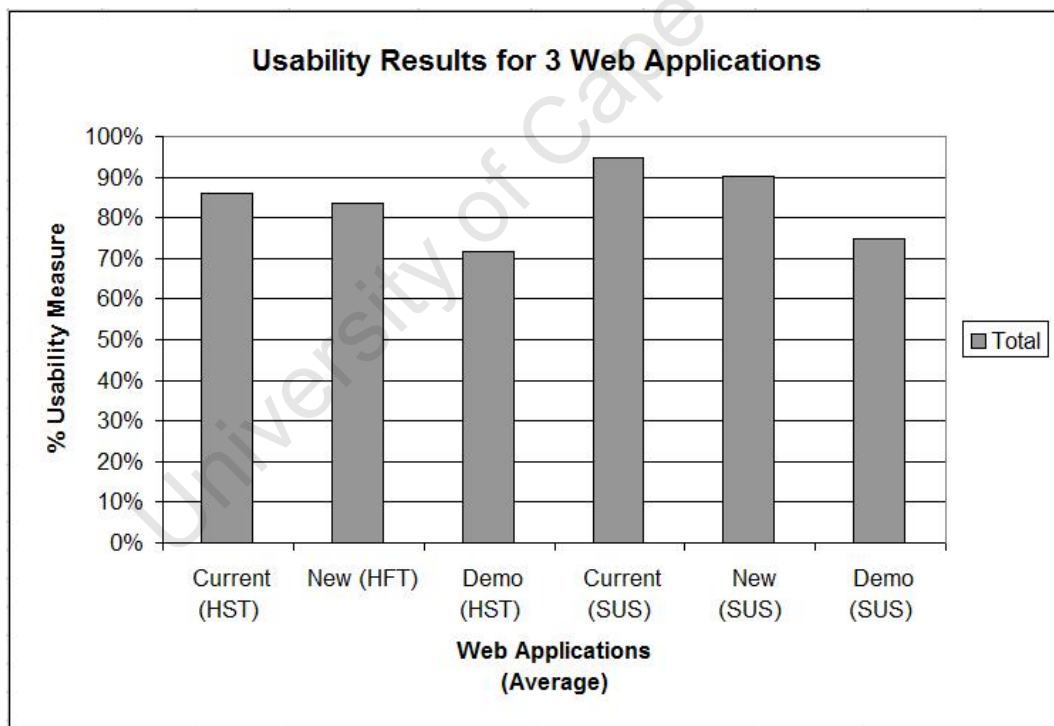


Figure 5.1: Average usability scores for all 3 web applications

In the results of the general evaluation feedback, it is important to note that at least 80% of the users assessed correctly determined the system with the most and least functionality.⁷ In addition the overall HFT score for the web applications is set at 74%.

⁷These results can be found in Table B.9 of the Appendices

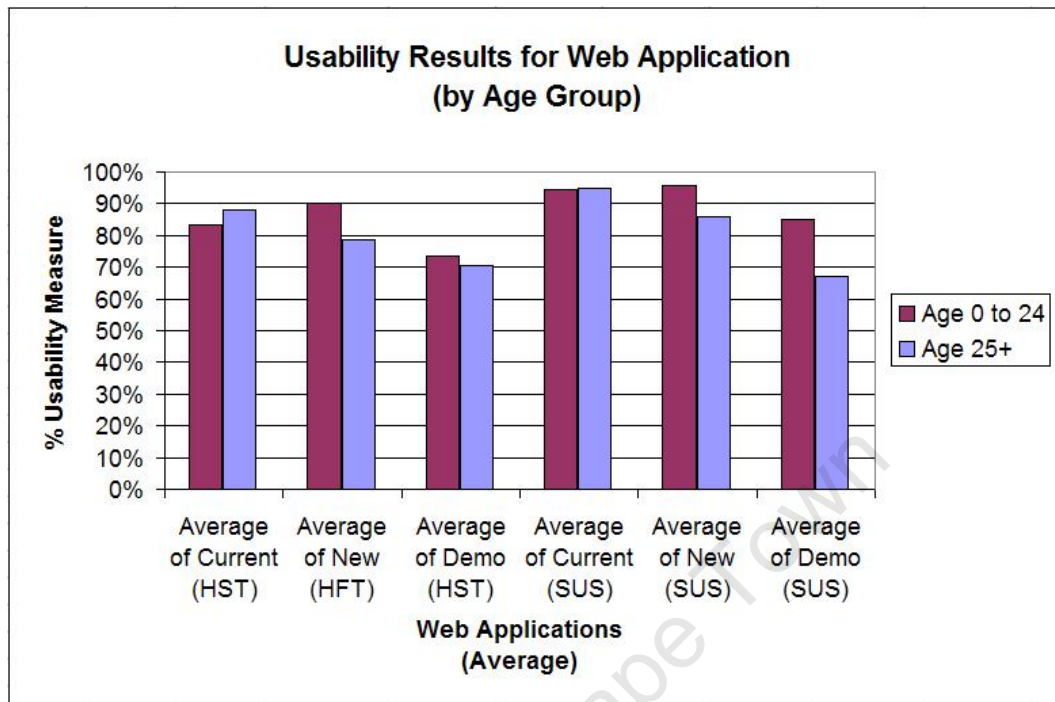


Figure 5.2: Average usability scores for all 3 web applications in terms of age group

The following is a summary of general points from users given verbally, or from the questionnaire regarding the web applications tested:

- Navigation menus on the left menu could be clearer.
- What is the purpose of System E (Demo site)?
- Enjoyed the very simple and uncomplicated interface.
- How do I check very old data records?
- Simultaneous connections to the server resulted in HTTP request delays.
- More use of colour in displaying and highlighting data is required.

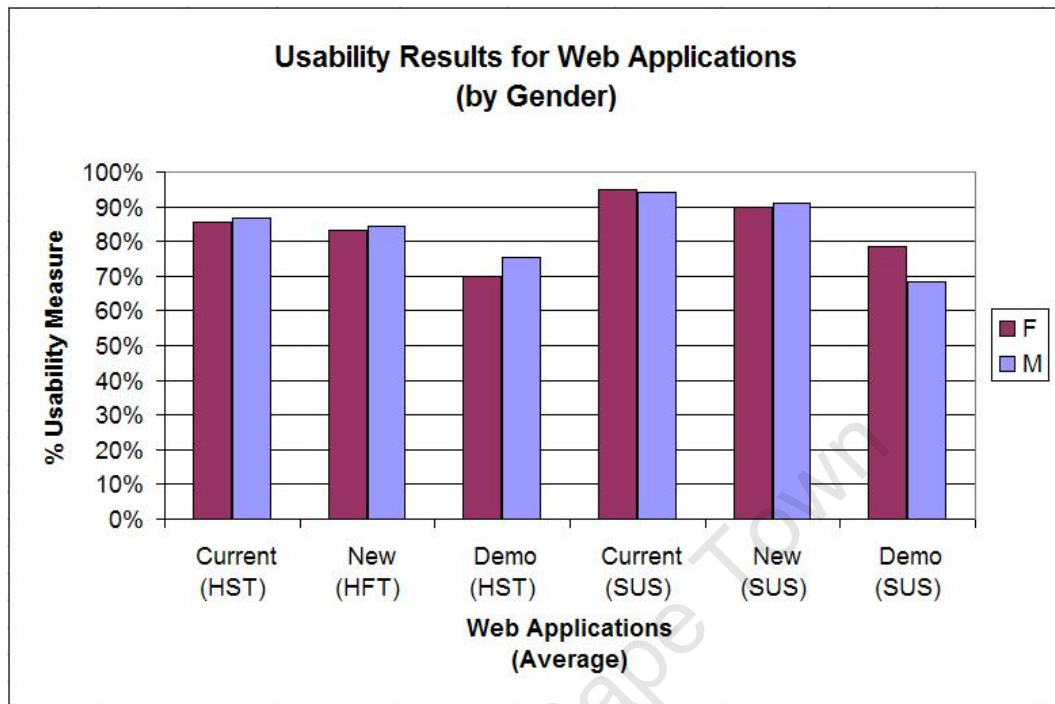


Figure 5.3: Average usability scores for all 3 web applications in terms of gender

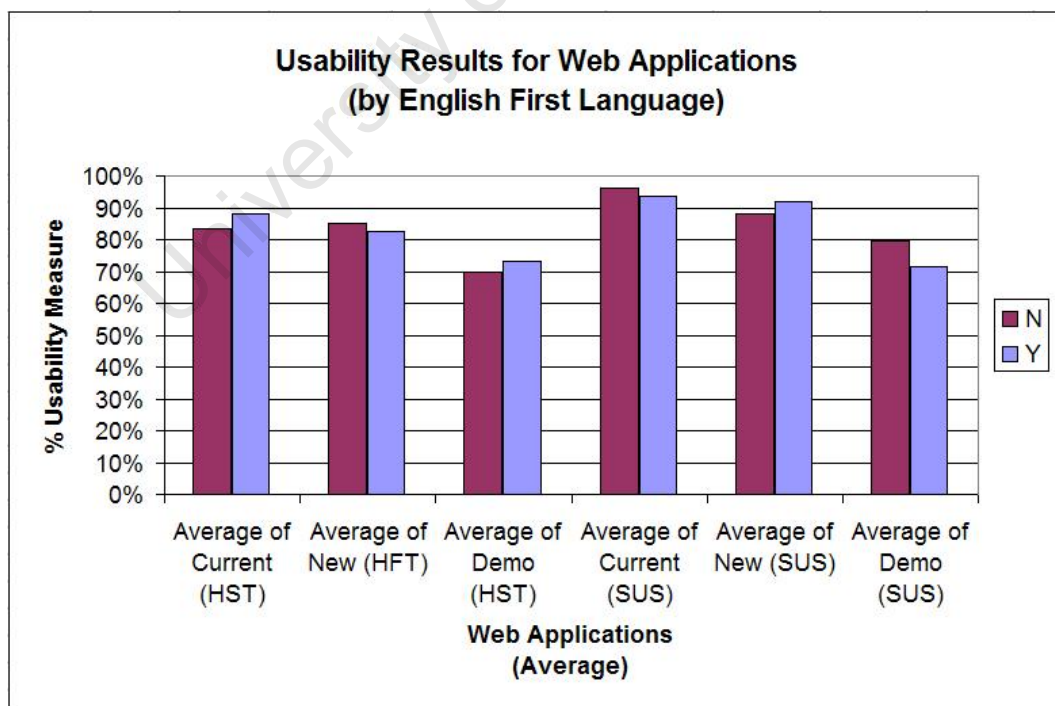


Figure 5.4: Average usability scores for all 3 web applications in terms of English first language

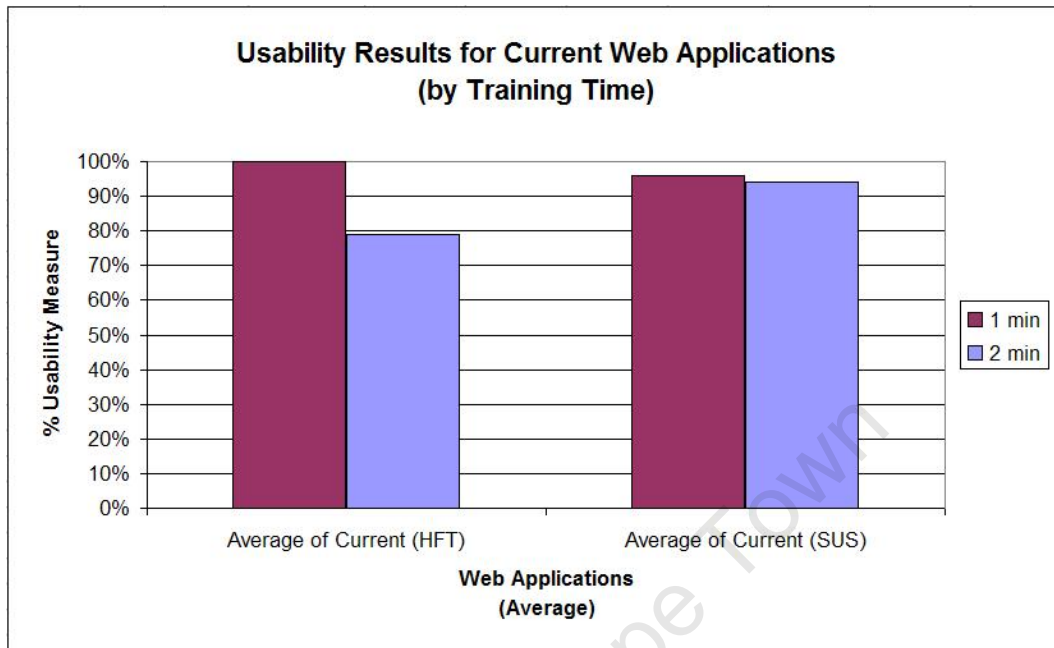


Figure 5.5: Average usability scores for all 3 web applications in terms of training time

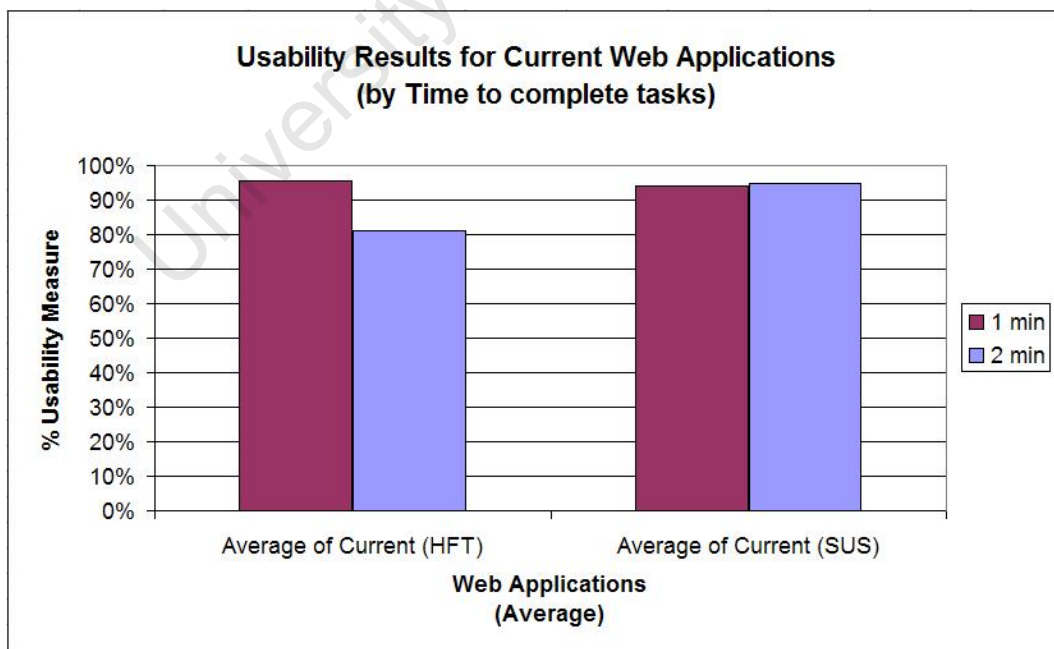


Figure 5.6: Average usability scores for all 3 web applications in terms of task completion time

Chapter 6

SERVERS

This chapter covers the identification of problems and modifications to three aspects of the server; communication, security, and system back up. A number of communication problems with the current prototype set up were identified through investigation. In addition, the prototype had no security or back up system implemented which is regarded as a potential threat due to the sensitive nature of the stored data. A high level of security and data redundancy was required when dealing with HIV/Aids patient information in order to maintain ethical standards upheld by the current development of legal policy. The second half of the chapter summarises the outcome of the client-side testing of the implemented developments and modifications.

6.1 Quantification of Problems and Modifications

Investigation into the problems and required modifications to the server have been isolated to three areas covered in this chapter:

1. Communication
2. Security
3. Back up System

6.1.1 Communication

As shown in Figure 6.1 (repeated from Chapter 2 for reader convenience), the central database is accessible via two networks, the Internet and the GSM network. Based upon the current implementation, the online Internet connectivity to the database server is not via an ISP but via the university LAN. This network connection is a 10 Mbps coaxial cable Ethernet LAN (Local Area Network) connection as shown in Figure 6.2. Ethernet is the most popular LAN technology and it is defined by the IEEE Standard 802.3. The use of a daisy-chain shared 10 Mbps coaxial connection in this set up is not sufficient for the required web application needs. It was found that university servers are connected on a 100 Mbps LAN using Unshielded Twisted Pair (UTP) Ethernet cabling that allows point to point 100 Mbps connections via packet switching using DHCP (Dynamic Host Configuration Protocol). The 100 Mbps LAN connecting all the servers is then connected to the wider Internet via an ISP.

To resolve the speed connection issue, 100 Mbps network cards were installed and tested on both servers, using a 100 Mbit UTP Ethernet LAN connection. The server network settings were reconfigured to a static IP via DHCP with permission from the IT network administration. A new location for hosting the servers was investigated and a server room with sufficient space for the servers was found within the engineering faculty and it is shown in Figure 6.3. Suitable hosting facilities are available in the corporate ISP environment, however due to the financial cost implications and the need for direct access to the servers, they are hosted at the university. The server room is networked into the main university network at 1 Gbps, with servers able to connect into the network hub at 100 Mbps. The server room is designed to be dust free and has a regulated temperature, both important requirements to ensure stable housing and hosting of servers.

Alternative Communication Methods

Alternative communication methods have been investigated for recommendations in possible future applications. From a web user point of view, Internet access in South Africa is now possible via Wi-Fi hotspots, Dialup, ISDN, ADSL, and satellite. In the urban environment, access to the Internet is widespread. However,

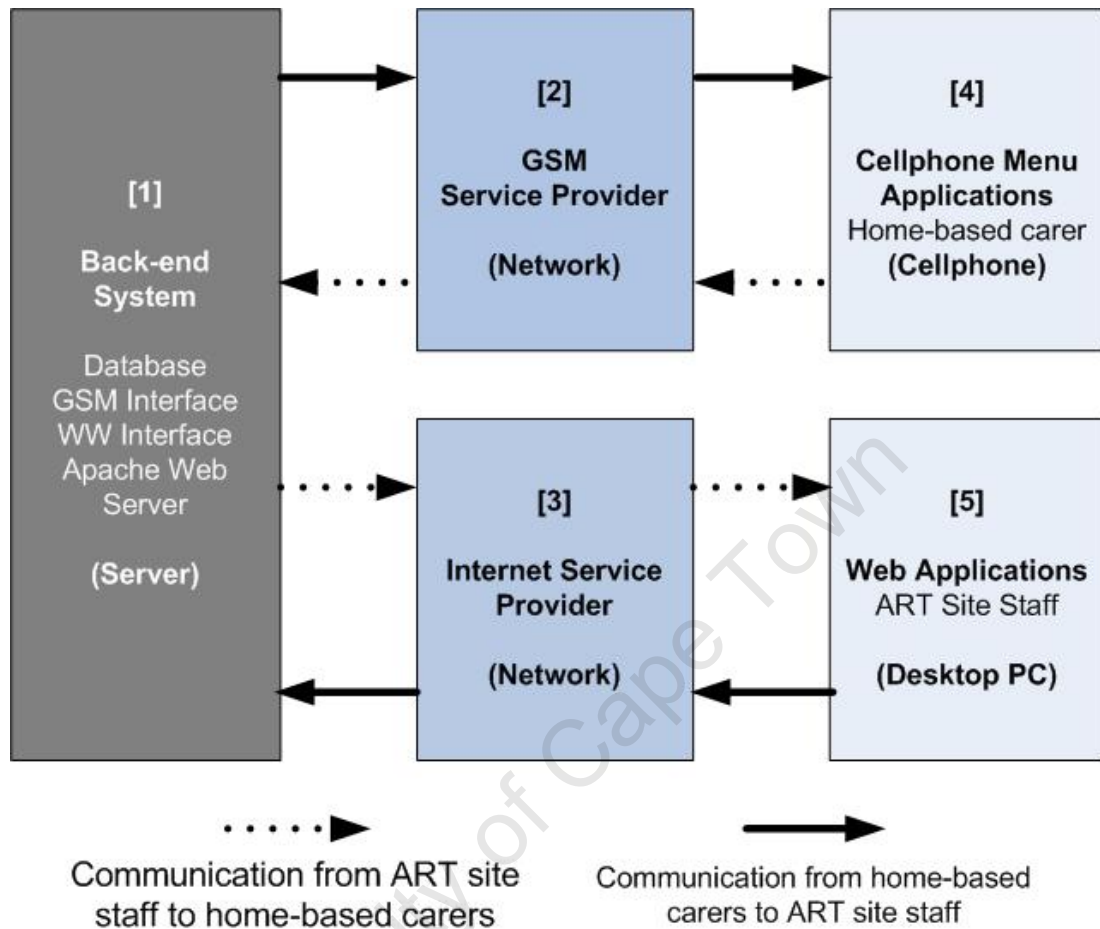


Figure 6.1: The five main technical components that make up the Cell-Life system (repeated)

the remote and rural environment is where the challenge lies for the access to the system. Satellite network access is only possible for one way communication of data; the user still needs to request data via a phoneline or cellular Internet connection. This allows for extensive remote connectivity opportunities for web users and highlights the need for fast reliable access to the back-end server.

The communication link possible between the GSM network and the WWW network is via a WASP (Wireless Application Service Provider). A WASP provides direct third party access of services provided by a GSM service provider. The major advantage of this connection is that cellular users can connect into the system, independently from their chosen GSM service provider. The connection between the database server and the cellular user is no longer via a GSM modem but via a network connection established by the WASP. At present, cellphones

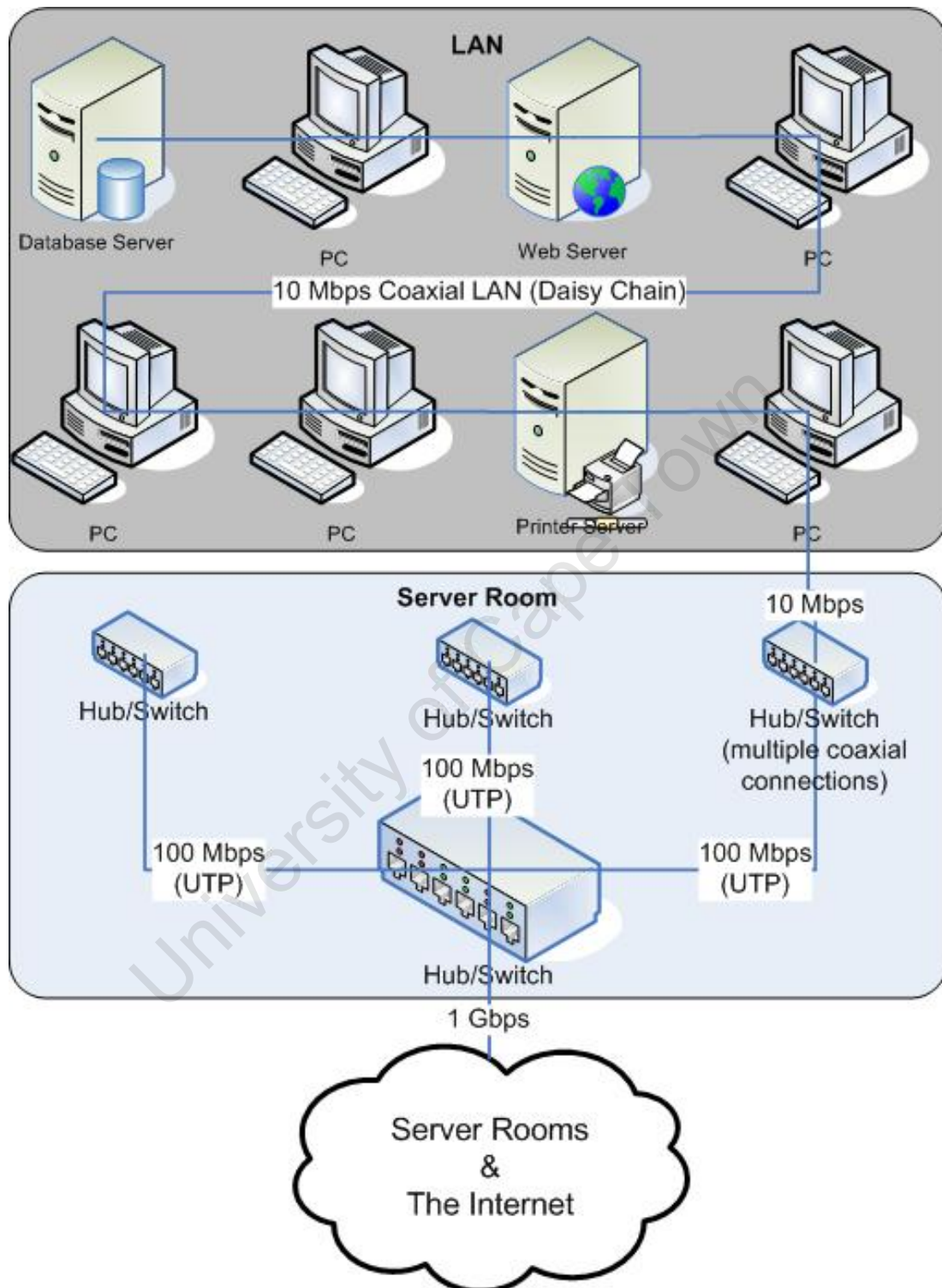


Figure 6.2: The current coaxial network connection to the database server

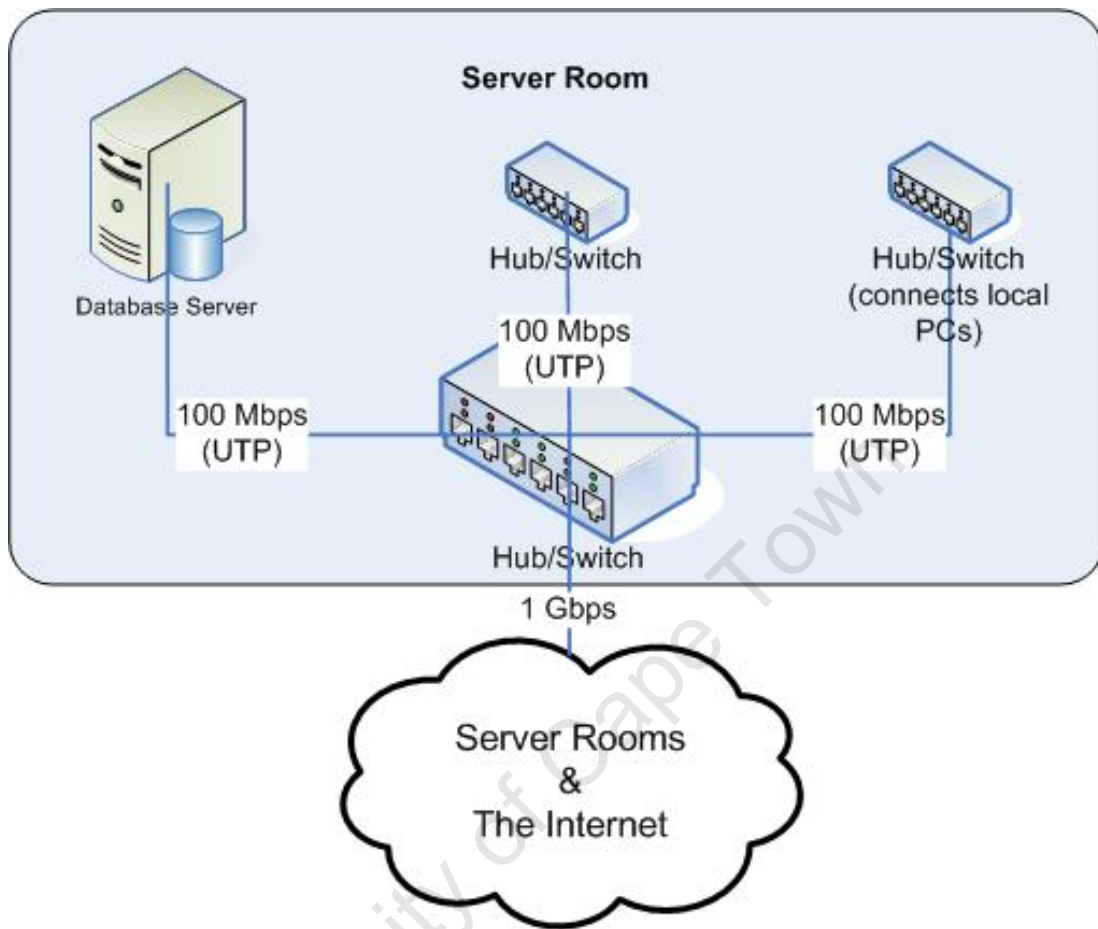


Figure 6.3: The new server room network connection to the database server

are integrated with digital camera technology which would allow photographs of symptoms to be taken and transferred to the database using MMS. USSD could result in the development of dynamic menu applications that could interface with the Cell-Life database through open sessions without the need for installed fixed menus used with WIG [40]. LBS would allow valuable location data to be collected and used in the development of spacial and GIS (Graphical Information Systems) databases. These are just a few of the many possible applications of cellphone technology advancements. No design and development stages are covered in this section, and relevant recommendations are made in Chapter 9.

6.1.2 Security

As seen in Figure 6.1, the system has two main communication paths to and from the central database, these being the Internet network and the GSM network. After investigation of the communication paths, it was found that no security was implemented on either network connection. Privacy and security when dealing with HIV/AIDS data is important due to legal, ethical and confidentiality requirements.

An unprotected network connection open to the Internet, combined with the running of various services and applications, makes a server vulnerable to countless security breaches and virus attacks. Therefore, the network connection needs to be protected and secured with a firewall.

An investigation of the services that use the network connection is also necessary. Establishing how these services operate allows the security threat to be evaluated and the related risk limited. The Apache web server is a network service running on the server. This allows the server to host and serve web pages onto the Internet. The web site and web-based login to the database are enabled through this service with the support of PHP scripts. There is no security enabled on the version of the Apache installed for HTTPS (Hyper-Text Transport Protocol Secure) connections to the server. Managing and controlling the user level access of each of the user levels is necessary for additional external and internal protection. The administration user in FreeBSD is called *root*. Root is the highest and most powerful level user in the system, and any applications run at the root user level have a direct effect on the security risk of the system. In addition, access to the database takes place at a user level through a command shell interface or via the Internet using scripts. These user level configurations are vital to securing the database and the internal security of the system. An example of this is shown by the Apache web server being installed with a custom user account for web-based activities such as the execution of CGI scripts.

Firewall

IPFW (Internet Protocol FireWall) is a common FreeBSD UNIX firewall. IPFW [18] is a system facility which allows filtering, redirecting, and other operations on IP packets traveling through system interfaces. Packets are matched by applying an ordered list of pattern rules against each packet until a match is found, at

which point the corresponding action is taken. The most important step in implementing a firewall is its configuration. A poorly set up firewall system is more of a security risk than not having one at all. A firewall can add another layer of security to the system, but it cannot stop a really determined cracker from penetrating the internal network [18].

The core of an operating system is the kernel. In FreeBSD, the IPFW software is compiled as a default part of the kernel. In order to enable IPFW, the kernel is reconfigured and recompiled. Once enabled, IPFW is configured using a number of alternative options. IPFW is initialised by configuring the *rc.conf* configuration file [18]. Another file *rc.firewall* contains the specific rules for the firewall. The firewall for the servers is configured to block all network ports by default and then to enable and allow certain ports depending on the required service.¹ Advice and input regarding the setting up of the IPFW rules was obtained from K Gajjar.

IPFW is fully implemented on both the main and back up servers. No problems have been encountered, however, the rules must be continuously monitored depending upon changes in security threats, or when new applications and services are installed.

SSL

Apache version 1.3.26 is installed as the web server. HTTPS is the standard encrypted communication mechanism on the WWW and it is actually HTTP over SSL [54]. HTTPS provides secure, encrypted connections from the web browser of a remote user to the database server.

In order for Apache to serve HTTPS connections from the server, the configuration file *httpd.conf* of the protocol server *httpd* is edited accordingly. Once this is done, a digital security certificate is required to provide the SSL encryption. The following description of the the functionality of a security certificate is from the Apache website [54]:

“The RSA private key file is a digital file that you can use to decrypt messages sent to the server. It has a public component which the server distributes (via the server Certificate file) which allows users to encrypt messages to the

¹A sample of the firewall configuration rule file can be found in Appendix A.7

server. A Certificate Signing Request (CSR) is a digital file which contains the server public key and server name. The server sends the CSR to a Certifying Authority (CA) to be converted into a real Certificate. A Certificate contains the server RSA public key, the server name, the name of the CA, and is digitally signed by the CA. Browsers that know the CA can verify the signature on that Certificate, thereby obtaining the server RSA public key. This enables users to send messages which only the server can decrypt.”

For this research study, a certificate was not obtained from or verified by a CA. The reasons for this were based upon the need to research the viability of the security option, the current low number of web users, the ability to create a non-verified certificate for testing, and the costs associated with an official CA verified certificate. The implementation of a non-verified certificate results in a web user having to receive a warning message when attempting to make an HTTPS connection to the server. At this point the certificate can be manually accepted. Once accepted, HTTPS connections are enabled. A CA validated certificate is automatically accepted at the point of request when the CA confirms the public key and server name with the certificate, resulting in an HTTPS connection.

Security certificates can be created using OpenSSL. OpenSSL is a cryptography toolkit implementing the SSL and Transport Layer Security (TLS v1) network protocols and related cryptography standards required by them [18]. Using OpenSSL, a security certificate is written and configured for use with the Apache web server. The installation of the certificate has resulted in the server’s ability to serve secure HTTPS pages. HTTPS is used from the first login page right until a web user logs out and exits the website, providing secure 128bit SSL encryption of the HTTP connection between the web user and the database server.

External Security Advice

A technical advisory meeting with FreeBSD specialist, K Gajjar of UUNET South Africa (SA) was held in May 2004. UUNET SA is one the leading Internet-based network service providers in Southern Africa. Specific to security of the overall system, the following steps were advised:

- Once satisfied with the outcome of the HTTPS capabilities of the server, purchase a verified SSL certificate from a CA.
- Continuous monitoring of the IPFW is necessary to maintain high security

levels.

- Consider a system architectural design based upon the separation of the server functionality and components into different servers for increased security and redundancy. Three levels are recommended:
 1. Static web server secure and fully accessible to the WWW, used to host the Cell-Life website
 2. Data query server forming a middle level of aggregated data from the main server database server, that is only accessible by the static web server through a secure protected SSL connection
 3. Data processing and storage server that is used to house the main database with no connection to the WWW and a single dedicated link to the data query server.
- Couple all of the above servers with back up systems based upon tape, and hard disk mirrors using a RAID (Redundant Array of Inexpensive Disks) configuration.

The external security advice from K Gajjar was sought purely from an investigative point of view and the subsequent recommendations are made in Chapter 9.

In the implementation stage of the security updates, it was found that an area overlooked in the security investigation was the PHP login files used by web users to access the Cell-Life system. Further research and investigation found that there are a number of security vulnerabilities when using PHP [15]. An online source with relevant PHP security information is noted in the recommendations in Chapter 9.

6.1.3 Back up System

An investigation into the database server set up found that no implemented back up system was in place. A second identical server, running the same FreeBSD operating system and software as the main server, was set up as the back up server. A back up system is required to back up the database and vital log and configuration files.

The first step towards developing a back up system between the two servers, would be the installation and configuration of second network cards. This would allow a 100 Mbit cross-over connection, forming a private sub-net to be constructed between the servers, that would be independent of the Ethernet LAN. NFS (Network File System) [18] allows a system to share directories and files with others over a network. By using NFS, users and programs can access files on remote systems as if they are local files. The installation of NFS on both servers over the private sub-net would create a connection between the servers which is equivalent to internal folder access. Shell scripts on the main server are then used to make back up copies of important files and data on the back up server. Shell scripts on the back up server then make multiple timestamped copies of the back up data that are not accessible from the main server through NFS. The scheduling of these scripts is carried out using the *cron* utility. Essential to the scheduling is the need for time delays and timestamps in writing back up data. These time delays provide a window period so that data losses are not immediately written over the same location at multiple points.

The PostgreSQL database can be exported through a database dump. *Pg_dump* is a utility for saving a PostgreSQL database into a script or an archive file [55]. The script files are in plain-text format and contain the SQL commands required to reconstruct the database to the state it was in at the time it was dumped. This is the method used to back up not only the database, but also the information required to completely reconstruct the database from the bottom up. System reliability and database redundancy was further improved through the installation of a UPS (Un-interruptible Power Supply) to provide the system with sufficient power to create a data back up and perform a controlled shutdown sequence. Finally, advice from K Gajjar regarding a long term back up system plan is also presented in the recommendations in Chapter 9.

6.2 Client-Side Testing

6.2.1 Communication

As the server is now configured with 100 Mbps network cards and installed in a server room using UTP cabling to connect to the university LAN, from an

architectural point of view remote access to the server is expected to be more effective. The server room is networked to the main university network at 1 Gbps and then via an unspecified connection to the Internet. The original server installation was on a 10 Mbps “daisy-chain” coaxial network. It is important to note that this type of connection shares the 10 Mbps bandwidth with all the connected users. Due to packet switching, UTP is capable of providing a point to point 10 Mbps connection. As the original “daisy” network has been removed from the building and upgraded to UTP, it is not possible to carry out a comparative test and assessment of the two connections. However, in order to demonstrate the capability of the new set up, a testing programme written in Java was created with the support of D de Jager and some online resources. Concurrent HTTP requests to the web application login page were carried out in quantities of 10, 20, 50 and 100 requests from within the university LAN, and from the Internet, using a local 512kbps ADSL (Asynchronous Digital Subscriber Line). The results of these are summarised in Figures 6.4 to 6.7.

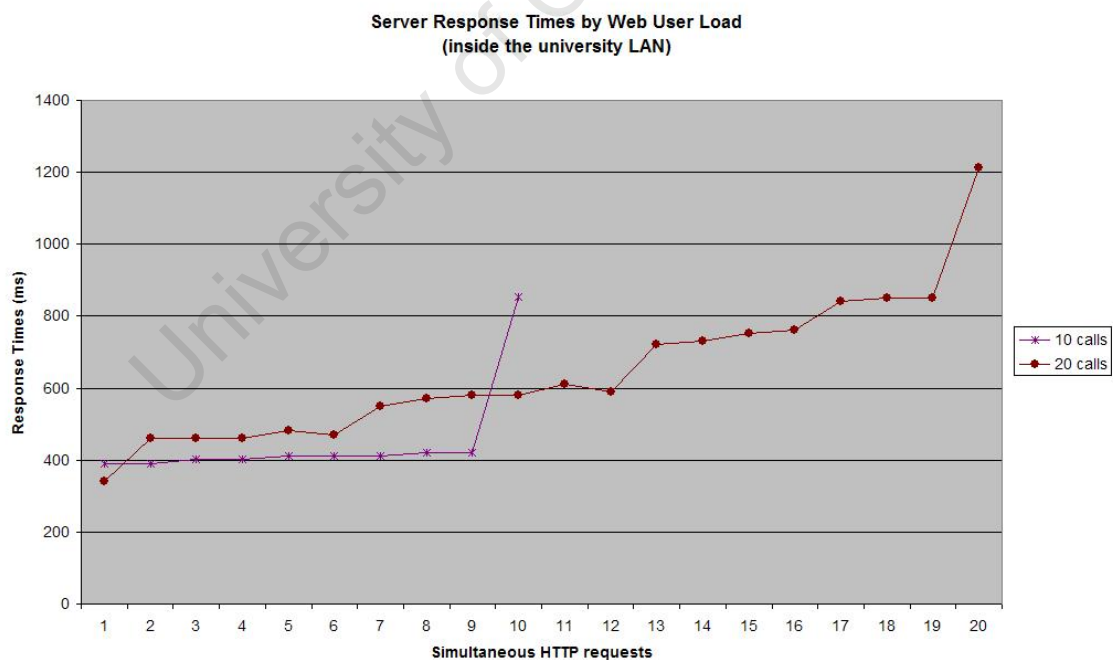


Figure 6.4: Web application server response time from internal LAN - Part 1/2

The relationship between web user HTTP request load and server response times is linear, with some step delays in processing. This allows predictions to be made about the maximum potential number of users within the university LAN and

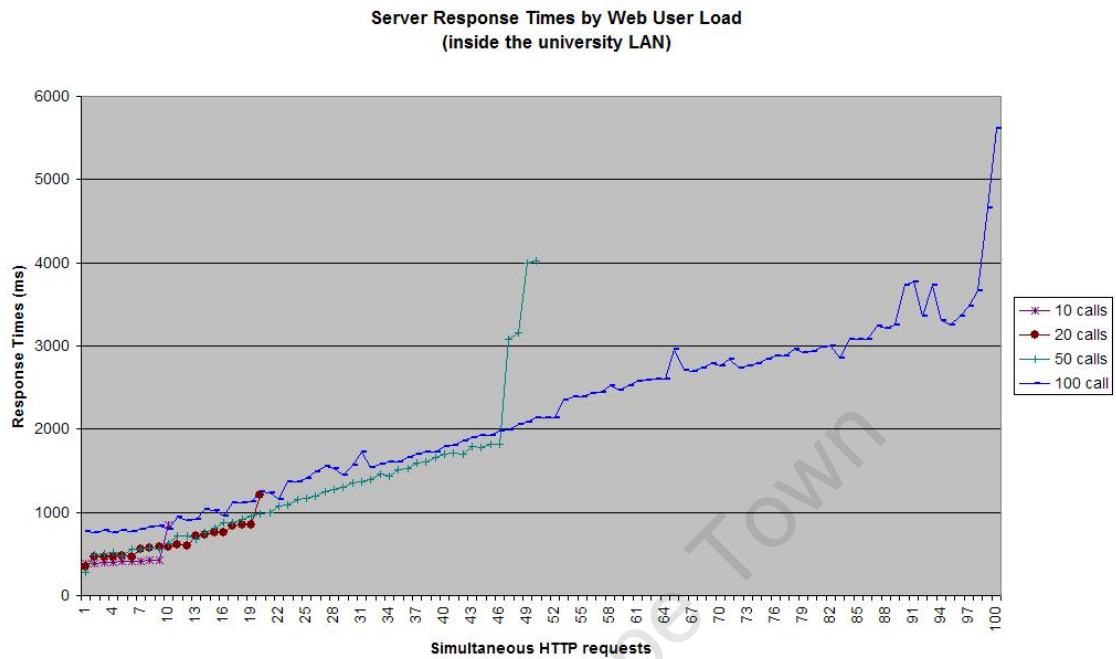


Figure 6.5: Web application server response time from internal LAN - Part 2/2

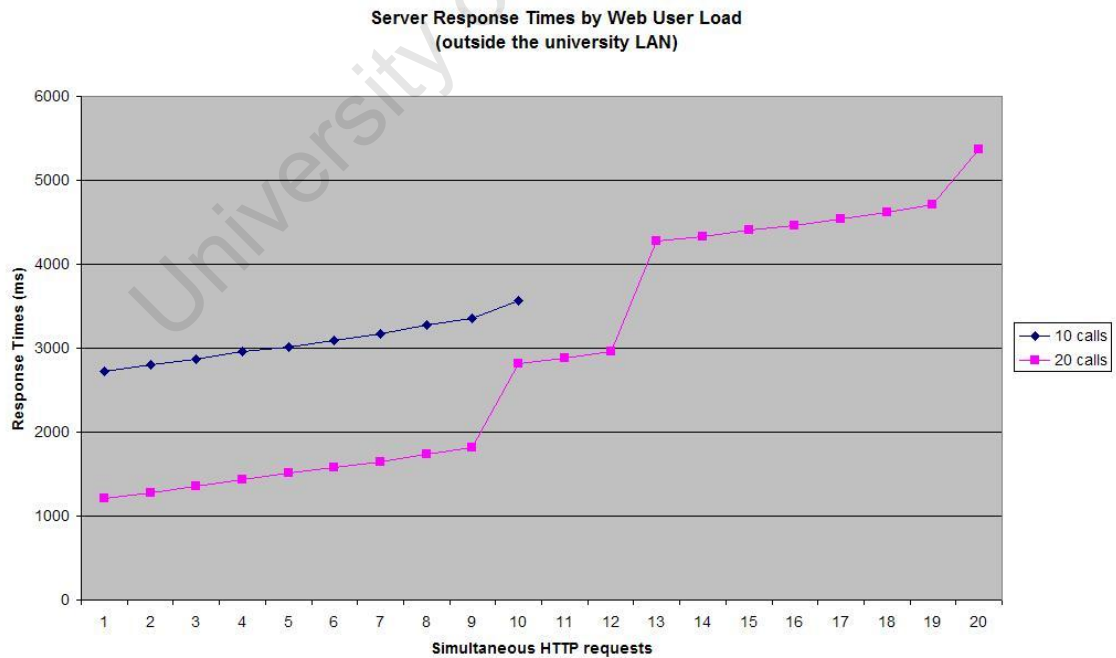


Figure 6.6: Web application server response time from the Internet - Part 1/2

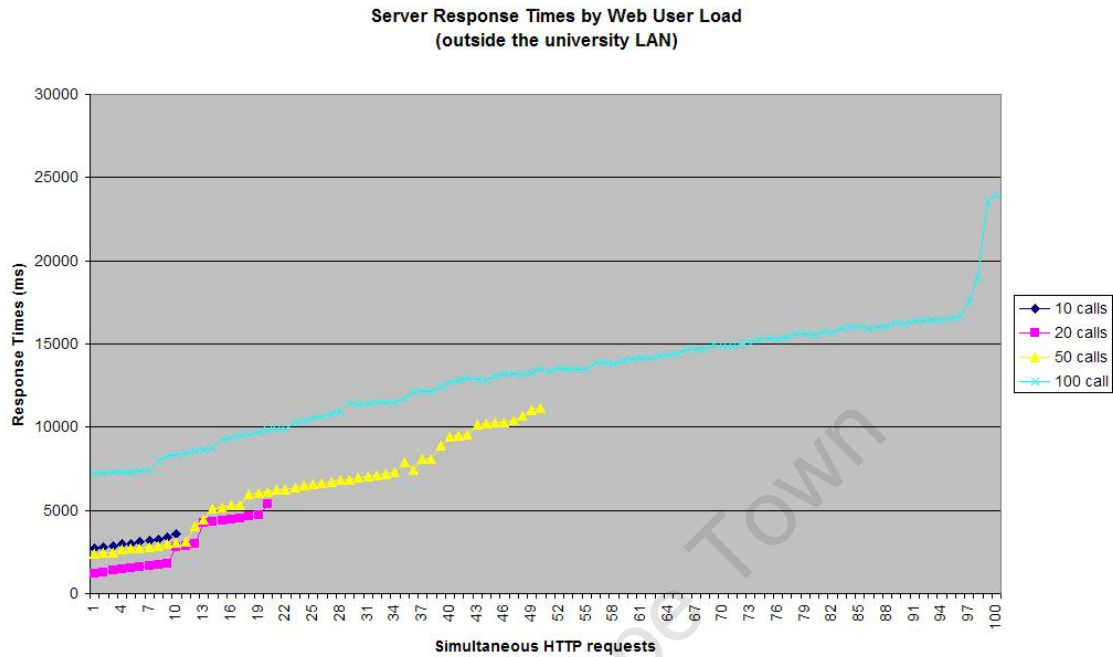


Figure 6.7: Web application server response time from the Internet - Part 2/2

from the Internet. The Internet connection used is from a local ISP and therefore representative of local connections at the same speed within South Africa. It can be seen that the slope of the graphs representing the linear increase in server response time to load result in very similar trends, however requests from the Internet are on average seven times slower than from within the university LAN. This is expected as the LAN is protected from external traffic congestions and it has relatively faster point to point speeds than connections over the Internet.

6.2.2 Security

The security of the system has been implemented by using SSL certificates providing HTTPS connections to web applications and the configuration and implementation of an IP firewall. It is noted that there is an increased level of subjective satisfaction from web users interviewed after a demonstration of the new security features. However, to test the technical capability of the now “secure” server, a technical associate at a local ISP volunteered to do an independent security check. After rigorous attempts to gain access to the system over the In-

ternet, a security vulnerability in the implementation of PHP was found. This directly affected the remote web application access to the database. As the vulnerability is a new problem (2005) recommendations have been made to counter this in Chapter 9.

6.2.3 Backup System

In order to test the back up system, a time-stamped archive copy of a database *dump* file was retrieved from the back up server. On an independent UNIX server installed with PostgreSQL, a restore of the database was carried out with no existing data. The entire database structure was successfully recreated and the contents of the database restored to the date of the back up process as intended.

Chapter 7

USER GUIDE AND TRAINING

There are two user types of the system: a cellphone user and a web user. The prototype system did not have any user guide or training material developed. This chapter is a report on the analysis of the basic user guide requirements for the cellphone users. Simple menu flow diagram training charts were developed for the current and the new cellphone menu applications. The training charts were used in a home-based carer training session at the Gugulethu pilot site as well as in a usability testing session. Feedback from both sessions with respect to user guide requirements and evaluation of the training charts was gathered and it is reported on at the end of the chapter.

7.1 User Analysis

There are two specific user groups that require user guides and training. The first being cellphone users who are the home-based carers at the ART site, and the second being web users or the ART site staff that require access to the patient data collected by the home-based carers.

7.2 Requirements Analysis

Cellphone menu application users and web users both require user guides covering the functionality of each application. The user guides should consist of two

components:

- a one page summary guide for mobile usage and quick reference
- a detailed guide with comprehensive information specific to each user's application

The user guides will be supported by a training programme for each user group. Problems encountered with respect to cellphone damage and theft will also be addressed through the training process.

Although the actual development of these guides is not within the scope of this research, an investigation into the requirements of a cellphone menu application user guide will be carried out followed by recommendations.

7.3 Task Analysis

The following tasks will be carried out in the user guide and the training programme development process for cellphone menu applications:

Tasks
Documentation of the complete functionality of the cellphone menu application
Investigation and identification of the human factors in each user group are to be investigated and identified
Investigation and provision of guidelines for safe and correct cellphone usage that will be included as a supplement to the detailed user guide

Table 7.1: Task analysis summary - user guide

7.4 Design and Documentation of Development

In order to understand and develop recommendations for a cellphone menu application user guide, the input from the user and task analyses were used to develop a first draft training chart. This had a dual purpose, to help train cellphone users

and to provide a graphical interpretation of the cellphone menus. This can then be used in a cellphone user training session in combination with assessment and feedback.

One of the main reasons for using this methodology relates to certain human factor considerations. Firstly, the cellphone users are people from a disadvantaged background in an economically poor township society. Secondly, for all of the cellphone users, English is a second language and none have more than a high school education level. Experience in using a cellphone would be above average, but exceptions need to be considered.

In order to navigate the menu, a logical flow exists, and it was decided to map these flows into a chart, as is commonly done when representing a menu system. As the current menu follows a tree structure and the new menu is a cyclic structure, the charts were based upon these respective structures. Figures 3.3 and 3.4 in Chapter 3 and Figures D.1 and D.2 in Appendix D are examples of the training charts developed. Alternative options that were considered included the use of a spreadsheet to indicate the flow and the depth of the menu levels or the inclusion of cellphone screenshots at each stage of the menu.

In terms of correct and safe cellphone handset usage the following points were noted and included with the training chart for users:

- Do not expose the cellphone to water or any other liquids.
- The cellphone battery is to be correctly charged to capacity and used completely before recharging.
- Care should be taken to avoid damage from dropping the cellphone.
- In the case of theft or loss, notify the ART site manager immediately and file a police report.

7.5 Usability Testing

The training charts for the three new menu applications were used in a training session with 10 home-based carers. General feedback and comments were

gathered during the training.¹

A training chart was also developed for the current menu application, and used in conjunction with the charts of the new menus in the formal usability test carried out on the menus and covered in Chapter 3. At the end of the testing process, a simple evaluation questionnaire was completed by the users as shown in Figure B.6 of Appendix B.

Important points noted with respect to the development of the cellphone menu application training charts are:

- In general users very rarely take the time to understand the chart and its contents, preferring to use and practise with the actual device immediately. The chart is then only used as a back up information source when the user gets lost in the menu or makes an error.
- The interpretation of abbreviations for second language English speakers was noted as a problem by users, as in certain instances the interpretation and meaning was not correct.
- The menu itself in English was not a problem as ARV drugs and certain terms and instructions are only in English, but having instructions in a user guide in a local language in combination with English would be beneficial.
- Without a clear purpose for the use of the menus, acceptance and usage by home-based carers is difficult and this should be incorporated into the user guide with input from the ART site staff.
- The flow chart was regarded as useful but not very representative of the actual cellphone menu. An example is that the chart allows for two dimensional navigation and movement but the menu itself has a fixed screen with a menu structure that has “depth” but not width or height.

The formal usability testing session provided insight into the usefulness of the training charts as shown in Figure B.6 of Appendix B, and the results are summarised as follows:

- All users agreed that the training chart had a logical flow.

¹Photographs of this can be seen in Appendix C.2

- 75% of users agreed that a cellphone menu screenshot at each stage of the menu would be useful.
- 83% of users found the chart useful in learning the menus.
- 88% of users found the chart useful when navigating the menus.
- 75% of users found the found the logical flow useful.
- The overall usability and usefulness of the training charts was rated at 73%.

University of Cape Town

Chapter 8

DISCUSSION

This chapter is a summary and discussion of the development, results and findings from Chapters 3 to 7.

8.1 Cellphone Menu Application

Three new cellphone menu applications were developed in order to reduce the cost of SMS data collection for the ART site, to reduce the number of SMS submissions, and to include additional socio-economic data and adherence problems using WIG. The usability testing stage brought a number of interesting aspects to the fore.

The first relationship encountered was the trade off between the usability and the complexity of the menus. To cater for the increased functionality requirements of the new menu, the menu increased in complexity by the number of variables collected and the method used in collection. In order to collect all the required information in as few SMSs as possible, innovative WML programming methods were used. Examples of this were storing a wider range of variables in the application, and developing an acyclic menu structure within the constraints of WIG. The relationship between the increased complexity and the reduced usability is demonstrated in the comparison of both menu systems. The 3 new menus are able to collect 58 variables using 3 SMSs, in comparison to the current menu that can collect 29 variables using 9 SMSs. Therefore, there has been a

50% increase in variable collection, and a 67% reduction in number of SMSs sent which translates into an SMS cost saving of 75%. The resulting increase in complexity through improved functionality is traded with a 15% reduction in usability according to the HFT and SUS tests.

Due to a homogenous usability testing group with respect to education level, cellphone and computer experience and language, these human factors had no influence on the outcome of the results. However, short-term learning was clearly demonstrated with two user groups using different testing devices (PC and cellphone) significantly reducing their task completion times in the second round of testing. In addition, the influence of device and task completion time on usability testing scores have been highlighted. In general, the cellphone testing produced the better usability results possibly due to familiarity and reduced interface complexity in comparison to the PC cellphone simulator test. In addition, valuable general feedback was recorded from users in the usability testing session.

8.2 SMS Data Submission and Database Integration

The two reasons for SMS data communication losses were identified as being the failure of initiation of Kannel software at server reboot, and network IP configuration problems resulting in CGI script execution failures. Only in the second identified problem was permanent data loss not avoided. Corrective measures were established to solve both problems.

Modifications were made to the database in order to accommodate the three new cellphone menu applications. In addition, a new method of variable substitution was successfully carried out using database lookup tables instead of CGI script substitution. CGI Perl scripts are still used to extract the data from incoming SMSs and to insert them into the database.

WIG security was investigated through meetings with an external WIG security expert. Recommendations are put forward in the next chapter regarding the findings of this investigation. At present, due to the alphanumeric variable substitution used in the cellphone menu applications, vulnerable and insecure SMS

data is not at risk unless access is given to the lookup table. Patient clinic identity numbers are used over the cellphone menus, further providing confidentiality and integrity of the remotely communicated data, as even with a lookup table the information cannot be personally linked to a patient.

The incoming SMS data collection process passes through three stages: the GSM modem, the CGI Perl scripts and finally the database tables. If a message makes it past the first stage, a permanent log record is kept of the transaction as well as the SMS contents. Therefore errors past this point do not result in permanent data loss. However, the GSM modem is the rate limiting stage of the data collection process, as this link is only capable of allowing incoming SMSs one at a time. The scripts and database are able to carry out multiple concurrent transactions per second and are therefore limited in transaction operation speed by the GSM link. Tests of the SMS transfer times for individual and group SMSs show how the GSM network operator spools the incoming SMSs, resulting in a linear relationship between SMS quantity and GSM network transfer times.

8.3 Web Applications and Offline Demonstration Site

Web application updates were carried out to incorporate increased functionality such as: monthly SMS count and cost reporting, an outgoing web-based SMS service, and web access reporting to ART management staff. A guest user account set up was also developed with reduced functionality and access to falsified sample data. Finally, an offline version of the web application tools was developed to provide potential sites in locations without Internet access some insight into the operations of the web application component on any PC.

Usability testing was carried out on the three web application versions: current, new and demonstration. As expected, the increased functionality of the new application resulted in a slightly lower (less than 5%) reduction in usability scoring on HFT and SUS tests than the current web application. The demonstration web application scored the lowest due to its greatly reduced functionality. Additional human factor influences were investigated with only age showing any significance. It was noted that users over the age of 25 years were slightly more

critical in their evaluation of the systems.

8.4 Servers

Three areas of investigation and development were carried out in this section: communication, security and back up.

The remote web-based access of the system was improved by relocating the server to a server room location that provided a LAN network connectivity speed improvement of at least 10 fold. Load tests were carried out on the new set up with concurrent HTTPS requests made to the server, whilst monitoring the server response time from a local connection with the university LAN as well as from the outside via the Internet. The results show a linear relationship between web user access load and service response time. They also show that, on average, similar requests via an external SA ISP take 7.5 times longer than internal ones. This is an important consideration as most ART sites within SA will be accessing web applications over the Internet.

From a security point of view, the current system did not have security in place on the server, or for remote web application access. Investigation and development has resulted in the configuration and installation of an IPFW as well as SSL certificates for 128bit encrypted HTTPS access to web applications for web users. In addition, external security advice was sought and important points from this meeting were put forward as potential future recommendations.

A back up system was not in place, and after investigation, a back up system was developed and implemented. A complete restoration test was carried out successfully using time-stamped archived back up files.

8.5 User Guides and Training

The final stage of this research project was to investigate the requirements and needs of a cellphone menu application guide through a home-based carer training session and a usability testing session. A basic level cellphone menu application training chart was developed as a first phase draft user guide. Through an

actual training session with home-based carers, a range of qualitative feedback was collected. The usability testing process found that the training charts were useful, but required more development which is covered in the next chapter.

University of Cape Town

Chapter 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The aim of this project was to answer the research question:

Can the prototype engineering concept be transformed into an effective solution to support the public health sector ART challenges in the developing world?

The research question has been answered through the investigation and development of the prototype solution in terms of the objectives listed in Section 1.3 that have been achieved.

Cellphone Menu Applications

The following conclusions are drawn with respect to the cellphone menu applications:

- Feedback from the two user groups of the system resulted in a participatory design-based approach to developing three new cellphone menu applications to replace the original menu and to include data related to adherence problems and socio-economic aspects.
- The new menus are capable of carrying out 50% more data collection at a 75% SMS cost reduction for the ART site. This was achieved at the

expense of an estimated 15% reduction in usability.

- Security and data transmission speed improvements to the WIG SMS communication data path were investigated but could not be developed or implemented. This was due to the assessment and validation requirement constraints of the GSM service provider. This process can only take place once final versions of the current WIG menu applications are developed and implemented on a larger scale. This would also entail additional monthly connection costs that would need to be assessed and budgeted.
- The three new cellphone menu applications are successfully linked into updated tables in the database using amended Perl scripts.
- WML programming difficulties encountered due to non-standard implementations of the technology by the GSM service operator and cellphone handset manufacturers have been noted and recorded in a document called the WML programming reference guide.

SMS Submission and Database Integration

The following conclusions are drawn in the area of SMS submission and database integration:

- The SMS data losses were investigated, identified and solved.
- The new cellphone menu applications have been integrated into the database by way of lookup tables and views as opposed to script variable substitution. The SMS communication software (Kannel) was reconfigured to collect the data from the new menus via amended and updated scripts for SMS data extraction and database insertion.
- Security implementation on the WIG applications and SMS communication path is possible but not currently necessary. Firstly, the validation process described above would be required, and secondly, the SMS data content in its current format is not interpretable and cannot directly be linked to a patient and therefore it holds no risk of confidentiality problems.
- The rate limiting point of data collection process was identified as being the GSM modem link, and performance tests were carried out.

Web Applications and Offline Web Site

From a web application and offline web site point of view, the following conclusions are drawn:

- SMS reporting and web-based SMS sending features have been developed and implemented as part of the increased functionality available to web users.
- Additional web-based users have been successfully created and implemented including a guest user with limited access to the system.
- Usability testing showed that the new functionality did not significantly increase the complexity of the web applications for web users, with only a 5% score reduction in the new system.
- The offline web site application was successfully developed, however with a very limited range of functionality.
- An offline demonstration website was successfully developed using HTML.

Servers

The following conclusions are drawn with respect to the servers:

- An investigation and implementation of improvements to the server network connection speed and remote web user accessibility problems was successfully carried out.
- Server security was investigated, and security implementations included a network firewall and a security certificate for secure HTTPS connections.
- A back up system was developed and implemented on the Cell-Life servers to provide data redundancy in the database and the system configuration files.

User Guides and Training

The following conclusion is drawn in terms of the user guide development:

- Feedback and input was gathered from cellphone users during a training session with home-based carers from the Gugulethu pilot site, as well as from a usability testing session based upon developed basic training charts.

As all the objectives of this research investigation have been met, it can be concluded that the prototype solution can be transformed into an effective solution to support the public health sector ART challenges. However, the stages carried out in this investigation are the building blocks of the system development process and recommendations for further research are made in the following section.

9.2 Recommendations

The following recommendations are made for future work based on this project:

- Develop the current WIG application menus to a level suitable for assessment and validation by the GSM service provider.
- Ensure that all future system developments are in line with the usability feedback as set out in this investigation, and work towards improving and increasing usability.
- Consider establishing a network based connection between the GSM service provider's WIG server and the Cell-Life server. This will result in improved data communication speeds, as well as providing the required platform for GSM data path security.
- Alternatively, investigate third party access to the GSM service provider services through a WASP such as Integrat (www.integrat.co.za).
- Investigate the development and implementation of alternative GSM communication technologies, namely USSD, GPRS, MMS and LBS.

- Further investigate the role of Java applications (MIDP) as a substitute replacement for WIG in the future.
- Further develop the WML programming reference guide.
- Develop a cellphone data collection user guide to be used when implementing the Cell-Life system at new ARV sites for training, based upon the input from the training session and usability testing session.
- Consider the development of a second generation database system that is based upon a more flexible interface such as Java for web-based access. Consider basing the architectural system design on the advice from K Gajjar. Such a system would support increased levels of security and system reliability.
- Continuously investigate and develop the security of the servers, as security is a dynamic and progressive field. Investigate the security vulnerabilities of the implementation of PHP in web-based scripting as confirmed by the independent ISP contact security check [15].
- Develop a long term back up system plan based upon the advice given by K Gajjar. This system should be designed not only towards data redundancy, but also server reliability and safety critical design that would allow the back up server to take on the full system functionality in the event of a main server failure. An additional feature could be an SMS notification to the system administrator, when the system shuts down due to a power failure (based upon the UPS serial port trigger) or whenever the system reboots.
- Consider hosting the Cell-Life servers at an ISP. This would result in a significant increase in national and international Internet bandwidth access to the servers. Also the servers would be housed in a very safe, secure and robust data warehouse environment.
- Develop an updated offline demonstration based upon the newly updated Cell-Life website (www.cell-life.org).
- Continue development of the Cell-Life system in an open-source environment. The current development and application of open-source technology

is proving to be successful and effective for the development of the low cost solutions required in the financially constrained public health sector in tackling the challenges of ART.

University of Cape Town

Bibliography

- [1] Actuarial Society of South Africa (ASSA): 2000 AID Model. [Online] Available: <http://www.assa.org.za> [Last accessed: 15 August, 2005], May 2004.
- [2] Actuarial Society of South Africa (ASSA): AIDS Committee. AIDS UPDATE 2002. Technical report, ASSA, April 2002.
- [3] Anand S.A., and Rivett U. ICT in the management of HIV treatment: Cell-Life - A South Africa Solution. *Convergence - Excellence in transition*, 6(3):56–59, July 2005.
- [4] Bekker LG., Orrell C., Reader L., Matoti K., Cohen K., Martell R., Abdullah F., Wood R. Antiretroviral therapy in a community clinic - early lessons from a pilot project. *South African Medical Journal* , 93(6):458–462, 2003.
- [5] Bridges.org. CASE STUDY: The SATELLIFE PDA Project. [Online] Available: http://www.bridges.org/iicd_casestudies/satellife/index.html [Last accessed: 25 April, 2004], December 2002.
- [6] Bridges.org. CASE STUDY: The Compliance Service uses SMS technology for TB treatment. [Online] Available: http://www.bridges.org/iicd_casestudies/compliance/ [Last accessed: 25 April, 2004], December 2003.
- [7] Brooke J. SUS - A quick and dirty usability scale. *Redhatch Consulting Ltd.*, December 2004.
- [8] Busgeeth K. The Use of Spatial Information Systems in the Management of HIV/AIDS: A Study of Gugulethu. Master's thesis, University of Cape Town, August 2003.

- [9] Caceres C., Gomez E.J., Del Pozo F. A patient monitoring tool for an HIV/AIDS integral care model. *Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE*, 4:3602–3605, 2001.
- [10] Cell-Life Research Project. [Online] Available: <http://www.cell-life.org> [Last accessed: 10 August, 2004], May 2004.
- [11] CellularOnline. [Online] Available: <http://www.cellular.co.za> [Last accessed: 17 August, 2004], May 2003.
- [12] CellularOnline. Statistics Of Cellular in South Africa. [Online] Available: http://www.cellular.co.za/stats/statistics_south_africa.htm [Last accessed: 7 August, 2004], May 2004.
- [13] Central Intelligence Agency (CIA). World Factbook - South Africa. [Online] Available: <http://www.cia.gov/cia/publications/factbook/geos/sf.html> [Last accessed: 12 July, 2004], May 2004.
- [14] Department of Health - Government of South Africa. *Operational Plan for Comprehensive HIV and AIDS Care, Management and Treatment for South Africa*, November 2003.
- [15] Developer.com. [Online] Available: <http://www.developer.com/lang/article.php/918141> [Last accessed: 12 August, 2004], April 2004.
- [16] Eighty20. Eighty20 Consumer Information Portal. [Online] Available: <http://www.eighty20.co.za> [Last accessed: 8 August, 2005], January 2005.
- [17] Finance24. Telkom proposes price cuts. [Online] Available: http://www.finance24.co.za/Finance/Companies/0,,1518-24_1589193,00.html [Last accessed: 14 October, 2004], October 2004.
- [18] FreeBSD UNIX. [Online] Available: <http://www.freebsd.org/> [Last accessed: 5 April, 2004], November 2002.
- [19] Frick P.A., Lavreys L., Mandaliya K., Kreiss J.K. Impact of an alarm device on medication compliance in women in Mombasa, Kenya. *International Journal of STD & AIDS*, 12(5):329–333, May 2001.

- [20] Fundamo. Funda-mentally mo-bile. [Online] Available: <http://www.fundamo.com> [Last accessed: 12 February, 2004], July 2003.
- [21] GSM World. Today's GSM Platform. [Online] Available: <http://www.gsmworld.com/technology/gsm.shtml> [Last accessed: 12 August, 2004], May 2004.
- [22] HCI Glossary by Jacques Hugo. [Online] Available: <http://www.usabilitysa.co.za/hcigloss.htm> [Last accessed: 5 September, 2005], September 2000.
- [23] Health Systems Trust (HST). [Online] Available: <http://www.hst.org.za> [Last accessed: 9 August, 2004], November 2003.
- [24] Hix D. & Hartson H.R. *Developing User Interfaces*. Wiley, 1st edition, 1993.
- [25] Health Systems Trust (HST). 2003/2004 South African Health Report (SAHR). Technical report, 2004.
- [26] Jakobsson M. HCI - Analysis and Design of Human-Computer Interaction. [Online] Available: <http://www.uwasa.fi/mj/hci/hci0.html> [Last accessed: 10 September, 2005], May 2005.
- [27] Jensen M. ICTs, Telecommunications, Internet and Computer Infrastructure in Africa. [Online] Available: <http://demiurge.wn.apc.org/> [Last accessed: 2 July, 2004], September 2003.
- [28] Johnson J. *Web Bloopers*. Morgan Kaufmann, 2003.
- [29] Jones M. & Marsden G. Mobile HCI Design. To be published by Dec 2005, July 2005.
- [30] Kannel. Kannel 1.3.2 User's Guide. Technical report, 2004.
- [31] Kannel: Open Source WAP and SMS gateway. Does mobile technology hold the key to widening access to ICTs in Africa? [Online] Available: <http://www.kannel.org/> [Last accessed: 7 April, 2004], January 2003.
- [32] Marlin C. & Brown L. *Human-Computer Interface Design*. Ablex Publishing Corporation, 1st edition, 1989.

- [33] Medical Research Council (MRC). [Online] Available: <http://www.mrc.ac.za> [Last accessed: 7 August, 2004], June 2003.
- [34] Miller, G.A. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capability for Processing Information. *Psychological Science*, 63:81–97, 1956.
- [35] Monday Paper (electronic) - University of Cape Town. Tutu lends his name to centre. [Online] Available: <http://www.uct.ac.za/generic.php?m=/news/emp/index.php?id=1923> [Last accessed: 20 August, 2004], August 2004.
- [36] Nielsen J. & Pernice K. A Useful Investment - Usability testing costs but it pays for itself in the long run. *CIO*, Feb 2001.
- [37] Nielsen J. *Designing Web Usability*. New Riders, 2003.
- [38] Nielsen J. useit.com: usable information technology. [Online] Available: <http://http://www.useit.com/> [Last accessed: 2 September, 2005], January 2005.
- [39] Nxumalo V. Cell-Life: A Needs Assessment Study for an HIV/AIDS Management Tool. Master's thesis, University of Cape Town, August 2003.
- [40] Parker M. *Investigation of Mobile Phone Technologies for the Cell-Life Project*. BTech Thesis, Cape Technikon, October 2003.
- [41] People and Planet. Treat AIDS Now - Treatment activism. [Online] Available: <http://www.peopleandplanet.org/stopaids/briefing.activism.php> [Last accessed: 31 July, 2004], July 2004.
- [42] PostgreSQL Open Source Database System. [Online] Available: <http://www.postgresql.org/> [Last accessed: 2 April, 2004], January 2003.
- [43] Reuters Foundation - Wanneburg G. South Africa says has fewer HIV/AIDS cases. [Online] Available: <http://www.alertnet.org/thenews/newsdesk/L28472738.htm> [Last accessed: 31 July, 2004], July 2004.

- [44] Safren S.A., Hendriksen E.S., Desousa N., Boswell S.L., Mayer K.H. Use of an on-line pager system to increase adherence to antiretroviral medications. *AIDS Care*, 15(6):pp. 787–793(7), December 2003.
- [45] SARPAN - Southern African Regional Poverty Network. Fact Sheet: Poverty in South Africa. [Online] Available: <http://www.sarpan.org.za/documents/d0000990/index.php> [Last accessed: 13 August, 2005], May 2004.
- [46] Shneiderman B. *Designing the User Interface*. Addison Wesley Longman, 3rd edition, 1998.
- [47] Silberschatz A., Korth H.F. & Sudarshan S. *Database System Concepts*. McGraw Hill, 3rd edition, 1999.
- [48] Skinner D. & Bloomberg C. Evaluation of use of cell phones to aid compliance with drug therapy for HIV patients. Technical report, Dept of Sociology, Faculty of Humanities, UCT, September 2003.
- [49] SmartTrust. WIG Application Creator. [Online] Available: <http://www.smarttrust.com> [Last accessed: 9 August, 2004], May 2003.
- [50] South African Advertising Research Foundation (SAARM). Living Standards Measure (LSM). [Online] Available: <http://www.saarf.co.za/lsm.htm> [Last accessed: 8 August, 2005], January 2005.
- [51] Statistics South Africa. [Online] Available: <http://www.statssa.gov.za/> [Last accessed: 12 July, 2004], July 2003.
- [52] Stringer L. Software Development. [MBA Lecture UCT GSB (Unpublished)], October 2005 (Unpublished).
- [53] TAC. The Treatment Action Campaign (TAC). [Online] Available: <http://www.tac.org.za> [Last accessed: 1 August, 2004], May 2003.
- [54] The Apache Software Foundation. [Online] Available: <http://www.apache.org.za/> [Last accessed: 5 July, 2004], November 2002.

- [55] The PostgreSQL Global Development Group. *PostgreSQL 7.2 Reference Manual*. Regents of the University of California., 2001.
- [56] Time Digital. [Online] Available: <http://www.time.com/time/digital> [Last accessed: 10 August, 2005], May 2005.
- [57] Treatment Action Campaign (TAC). First Report on the implementation of the Operational Plan for Comprehensive HIV and AIDS Care, Management and Treatment for South Africa (the Operational Plan). Technical report, TAC, July 2004.
- [58] UNAIDS. Joint United Nations Programme on HIV/AIDS. [Online] Available: <http://www.unaids.org>. [Last accessed: 15 July, 2004], May 2003.
- [59] UNAIDS. Report on the global hiv/aids epidemic. Technical report, UNAIDS, June 2004.
- [60] USAID. United States Agency for International Development. [Online] Available: http://www.usaid.gov/our_work/global_health/aids/index.html [Last accessed: 1 July, 2004], June 2003.
- [61] USAID. United States Agency for International Development's Strategy in South Africa. [Online] Available: http://www.usaid.gov/locations/sub-saharan_africa/countries/southafrica/ [Last accessed: 1 August, 2004], June 2003.
- [62] Webopedia. Online encyclopedia dedicated to computer technology. [Online] Available: <http://webopedia.internet.com> [Last accessed: 11 August, 2004], September 2003.
- [63] Whiteside A. & Sunter C. *AIDS - The Challenge for South Africa*. Human & Rousseau Tafelberg, Cape Town, 3rd edition, May 2001.
- [64] WHO and UNAIDS. Treating 3 MILLION BY 2005 - Making it happen - THE WHO STRATEGY. Publications of the World Health Organisation, 2003.
- [65] WHO and UNAIDS. Epidemiological Fact Sheets - South Africa. UNAIDS/WHO, 2004 update.

- [66] Wikipedia - The Free Encyclopedia. [Online] Available: <http://en.wikipedia.org> [Last accessed: 8 October, 2005], January 2005.
- [67] wordIQ.com. Definition of Pandemic. [Online] Available: <http://www.wordiq.com/definition/Pandemic> [Last accessed: 2 May, 2004], May 2004.
- [68] World Bank. Millennium Development Goals - HIV/AIDS. [Online] Available: http://www.developmentgoals.org/Hiv_Aids.htm#top [Last accessed: 18 June, 2004], July 2003.
- [69] World Health Organisation (WHO). *Scaling Up Antiretroviral Therapy in Resource-Limited Settings*. World Health Organisation (WHO), June 2002.
- [70] World Health Organisation (WHO). WHO and HIV/AIDS. [Online] Available: <http://www.who.int/hiv/aboutdept/en/> [Last accessed: 10 June, 2005], May 2003.
- [71] World Health Organisation (WHO). Antiretroviral Therapy (ART). [Online] Available: <http://www.who.int/hiv/topics/arv/en/#why> [Last accessed: 17 September, 2005], August 2004.
- [72] World Summit. ICT for Development Platform. [Online] Available: <http://www.ict-4d.org/> [Last accessed: 25 August, 2005], August 2005.
- [73] World Wide Web Consortium (W3C). [Online] Available: <http://www.w3.org/> [Last accessed: 14 May, 2004], June 2002.
- [74] Writing for the World Wide Web. South Africans Online: 'Digital Divide' and the Network Society. [Online] Available: <http://www.writing.uct.ac.za/what/southafrican.htm> [Last accessed: 1 August, 2004], April 2004.

Appendix A

Programming Code

A.1 CGI (Perl)

The following CGI Perl script is used to carve up the data in the incoming SMS into separate variables and insert the data captured within these variables into the database. A validation of the sender takes place prior to insert. If the sender (cellphone number) is not registered as a home-based carer in the database the insert will fail (bail).

```

1  #!/usr/local/bin/perl -w
2  #
3  # Insert for Cape Town - Gugs for Menu G2 - Monitor - Keyword 'g2'
4  #
5  # $Id$
6  #
7  use strict;
8  use Data::Dumper;
9  use CGI qw/'Vars'/;
10 use DBI;
11 use vars qw($DEBUG);
12
13 $main::DEBUG = 1;
14
15 #
16 # Sub prototypes
17 #
18 sub bail($);
19 sub valid_sender($$);
20 sub insert_g2_app_data($$);
21
22 #
23 # Main
24 #
25 my $cgi = new CGI;
26 my $dbh = DBI->connect('dbi:Pg:dbname=celllife','','',
27     {PrintError => 0, RaiseError => 1}) || die "Can't connect to db";
28
29 print "Content-Type: text/html\n\n";
30 my %data;
31
```



```

32 my %vars = Vars();
33
34 #
35 # Make sure that the cgi query string is passing all the information
36 # that we need
37 #
38 foreach my $required (qw{ message sender }) {
39     if (!exists($vars{$required})) {
40         bail "invalid cgi request";
41     }
42 }
43
44 my $message = $vars{message};
45 my $message1 = $vars{message1};
46 my $sender = $vars{sender};
47
48 if (!valid_sender($dbh, $sender)) {
49     bail "You are not autherised to send";
50 }
51
52 #
53 # Carve up the message
54 my $format = '1234567890:nev:199:21:lost'
55 #
56 #($data{patient_id}) = split(/:/, $message1);
57 ($data{mistake}, $data{patient_id}, $data{sym1}, $data{sev1}, $data{sym2},
    $data{sev2}, $data{sym3}, $data{sev3}, $data{sym_other}, $data{month},
    $data{day}, $data{time_am_pm}, $data{alert}, $data{visit_type}, $data{
    at_home}, $data{pill_count}) = split(/:/, $message);
58
59 $data{avail} = 1;
60
61 if(!insert_g2_app_data($dbh, \%data)) {
62     bail "Insertion of g2_app_data failed";
63 }
64
65 #
66 # Print some debug data to the httpd error log
67 #
68 foreach my $k (keys %data) {
69     print STDERR "$k = $data{$k}\n";
70 }
71
72 $dbh->disconnect();
73 exit();
74
75 #
76 # Check for a valid sender
77 #
78 sub valid_sender($$) {
79     my ($dbh, $sender) = @_;
80     my $statement = qq{
81         select id
82         from cellphone
83         where number = '$sender'
84     };
85
86     print STDERR "statement = $statement\n" if $DEBUG;
87     my $sth = $dbh->prepare($statement) || die "Can't prepare $statement"
88     ;
89     $sth->execute() || die "Can't execute $statement";
90     my ($return) = ($sth->fetchrow_array())[0];
91     $sth->finish();
92     print STDERR "return = $return\n" if $DEBUG;
93
94     if (defined($return)) {
95         $data{sender_id} = $return;
96         return 1;
97     } else {
98         return 0;
99     }
100 }

```

```

101
102 #
103 # Insert g2_app_data!
104 #
105 sub insert_g2_app_data($$) {
106     my ($dbh,$data) = @_;
107     my $time = time();
108     my $statement = qq{
109         insert into g2_app_data
110         (person_id,symptom1,s1_severity,symptom2,s2_severity,symptom3
111         ,s3_severity,symptom_other,month,day,time_am_pm,alert,
112         visit_type,at_home,pill_count,time,cellphone_id)
113         values
114         ($data->{patient_id},$data->{sym1},$data->{sev1},$data->{sym2}
115         ,,$data->{sev2},$data->{sym3},$data->{sev3},$data->{
116         sym_other},$data->{month},$data->{day},'$data->{
117         time_am_pm}','$data->{alert}','$data->{visit_type}','
118         $data->{at_home}','$data->{pill_count}',,$time,$data->{
119         sender_id})
120     };
121
122     print STDERR "statement = $statement \n" if $DEBUG;
123     my $sth = $dbh->prepare($statement) ||
124         die "Could not prepare $statement";
125     $sth->execute() || die "Execute failed : ".$dbh->errstr;
126     return(1);
127 }
128
129 #
130 # Print a message and exit
131 #
132 sub bail($) {
133     my $msg = shift();
134     $dbh->disconnect();
135     print $msg;
136     print STDERR $msg,"\ndata follows:\n",Dumper(\%data),
137         "\n-----\n" if $DEBUG;
138     exit();
139 }

```

A.2 PHP

Sample of index.php

Index.php is the script that is used when the user is logged into the database. This script allows the user to query the database through predefined functions. A screen shot of this page in a web browser can be found in Appendix D.2.

```

1  <? include("include/XYZ.inc"); include("include/123.inc");
2  include("include/ABC.inc");
3
4  $sidarray = explode("+", "$cellcookie");
5  //echo "cooky set and login $sidarray[0]";
6  if ((isset($cellcookie)) && (isset($sidarray[0])))
7  {
8      $query = "Select sid from web_user where username = '".
9      $sidarray[0]."'";
10     $timer = md5(time());
11     $sid = $sidarray[0] . "+" . $timer;
12     $query = "update web_user set sid='". $timer.
13     "' where user='$sidarray[0]'";

```

APPENDIX A. PROGRAMMING CODE

```

14     SetCookie("cellcookie",$sid,time()+$sessionTime);
15     //$sessiontime time in config file
16     connectToDB();
17     safe_query($query);
18 } else {
19     header("Location: login.php?reset=yes");
20     exit;
21 }
22 $query = "select * from web_user where username='$sidarray[0]'";
23 $result = safe_query($query);
24 $current_user = pg_fetch_array($result,0);
25 if ($current_user[5] == 1) $is_admin = 1;
26
27 ?>
28 <html>
29 <LINK REL="stylesheet" TYPE="text/css" HREF="include/wickedstyle.css" TITLE="
    formal">
30 <LINK REL="stylesheet" HREF="include/overlib.css" TYPE="text/css">
31 <!-- <SCRIPT LANGUAGE="JavaScript" SRC="include/overlib.js"></SCRIPT> -->
32 <HEAD><TITLE>CellLife.org Index page</TITLE></HEAD>
33
34
35 <!-- </script> -->
36
37 <body bgcolor="White" text="Black" vlink="#D73236" link="#AA0408">
38 <table width="100%" border="0">
39     <tr>
40         <td bgcolor="#000000">
41             <table width="100%" border="0" cellspacing="1">
42                 <tr>
43                     <td bgcolor="#FFFFFF">
44                         <table width="100%" border="0">
45                             <tr>
46                                 <td>
47                                     <?
48                                     echo "<div class=user>User: <b><font color=blue>$sidarray[0]</font>".
49                                     "</b>logged in<br>";
50                                     if (($state == "config") && ($sidarray[0] == "admin"))
51                                         echo "<a href=\"newuser.php\">Admin Users</a>";
52                                     echo "</div>";
53                                     ?>
54
55
56                                     <table border=0><tr><td valign="top">
57                                         <a href="<?=$PHP_SELF?>" ><? echo $count[$count]; ?><!--<span class="logo">
58                                             Cell Life</span>--></a>
60                                     <div class="front">
61                                     <?
62                                     $sid_upper = strtoupper($sidarray[0]);
63                                     echo "<div class=user>User: <b><font color=blue>$sid_upper</font>".
64                                     "</b> logged in. <b>CT - Gugulethu Clinic</b><br>";
65                                     if (($state == "config") && ($sidarray[0] == "admin"))
66                                         echo "<a href=\"newuser.php\">Admin Users</a>";
67                                     echo "</div>";
68                                     ?>
69
70                                     <a href="<?=$PHP_SELF ?>?action=home"><b>HOME</b></a> <br>
71                                     <br>
72                                     <b><u><font color="#0000FF">CELLIFE</font></b></u><br>
73                                     <a href="<?=$PHP_SELF ?>?action=g1_adh">G1 ADHERENCE</a> <br>
74                                     <a href="<?=$PHP_SELF ?>?action=g2_mon">G2 MONITOR</a> <br>
75                                     <a href="<?=$PHP_SELF ?>?action=g3_soc">G3 SOCIAL</a> <br>
76                                     <br>
77                                     <a href="<?=$PHP_SELF ?>?action=coun"><b>COUNSELLORS</b></a> <br>
78                                     <a href="<?=$PHP_SELF ?>?action=sms"><b>SMS SERVICE</b></a> <br>
79                                     <a href="<?=$PHP_SELF ?>?action=smsr"><b>SMS REPORTS</b></a> <br>
80                                     <br>
81                                     <u><font color="#0000FF">OLD MENUS</font></u><br>
82                                     <a href="<?=$PHP_SELF ?>?action=adh">ADHERENCE </a> <br>
83                                     <a href="<?=$PHP_SELF ?>?action=sym">SYMPTOM </a> <br>
84                                     <a href="<?=$PHP_SELF ?>?action=apt">APPOINTMENT </a> <br>

```


APPENDIX A. PROGRAMMING CODE

```

146         <td width="1%" height="14">&nbsp;</td>
147         <td colspan="4" height="14"><font face="Verdana, Arial,
            Helvetica, sans-serif" size="2"><b><!--Your
148             appointments for today are:-->You have no
            appointments for today.</b></font></td>
149     </tr>
150
151     <tr>
152         <td width="1%">&nbsp;</td>
153         <td colspan="4">&nbsp;</td>
154     </tr>
155     <td width="1%" height="14">&nbsp;</td>
156     <tr><td colspan="4" height="14"><font face="Verdana,
            Arial, Helvetica, sans-serif" size="2" color="#FF0000
            "><b>--> Use <a href="<?=$PHP_SELF ?>?action=smsr">
            $PHP_SELF ?>?action=sms">SMS SERVICE</a>.</font></td>
            </tr>
157     <tr><td colspan="4" height="14"><font face="Verdana,
            Arial, Helvetica, sans-serif" size="2" color="#FF0000
            "><b>--> Use <a href="<?=$PHP_SELF ?>?action=smsr">
            SMS REPORTS</a> to check stats on SMSs collected.</b>
            </font></td></tr>
158
159
160     </table>
161     <p>&nbsp;</p>
162     <p>&nbsp;</p>
163     <p>&nbsp;</p>
164     <p>&nbsp;</p>
165     <p>&nbsp;</p>
166 <!-- XXXX -->
167 <?>
168
169
170 if (!isset($action)) {
171     $action = "home";
172 }
173
174 if ($action == "home") {
175     // Add the home page here
176     home(strtoupper($sidarray[0]));
177 }
178
179
180 if ($action == "apt")
181 {
182     if (!isset($col)) {
183         $col = "report_time";
184     }
185     if (!isset($order)) {
186         $order = "desc";
187     }
188     if (!isset($limit)) {
189         $limit = 10;
190     }
191
192     $select = dbnav("Appointment Report", $action, "vw_appointment",
193         $col, $order, $limit,
194         "select * from vw_appointment");
195 }
196
197
198
199
200
201 if ($action == "adh")
202 {
203     if (!isset($col)) {
204         $col = "report_time";
205     }
206     if (!isset($order)) {
207         $order = "desc";
208     }

```

```

209     if (!isset($limit)) {
210         $limit = 10;
211     }
212
213     $select = dbnav("Adherence Report", $action, "vw_adherence",
214         $col, $order, $limit,
215         "select * from vw_adherence");
216 }
217
218 if ($action == "sym")
219 {
220     if (!isset($col)) {
221         $col = "report_time";
222     }
223     if (!isset($order)) {
224         $order = "desc";
225     }
226     if (!isset($limit)) {
227         $limit = 10;
228     }
229
230     $select = dbnav("Symptom Report", $action, "vw_symptom",
231         $col, $order, $limit,
232         "select * from vw_symptom");
233 }
234
235 if ($action == "alt")
236 {
237     if (!isset($col)) {
238         $col = "report_time";
239     }
240     if (!isset($order)) {
241         $order = "desc";
242     }
243     if (!isset($limit)) {
244         $limit = 10;
245     }
246
247     $select = dbnav("Alert Report", $action, "vw_alert",
248         $col, $order, $limit,
249         "select * from vw_alert");
250 }
251
252 if ($action == "vst")
253 {
254     if (!isset($col)) {
255         $col = "report_time";
256     }
257     if (!isset($order)) {
258         $order = "desc";
259     }
260     if (!isset($limit)) {
261         $limit = 10;
262     }
263
264     $select = dbnav("Visit Report", $action, "vw_visit",
265         $col, $order, $limit,
266         "select * from vw_visit");
267 }
268
269
270 if ($action == "g1_adh")
271 {
272     if (!isset($col)) {
273         $col = "id";
274     }
275     if (!isset($order)) {
276         $order = "desc";
277     }
278     if (!isset($limit)) {
279         $limit = 10;
280     }
281     $select = dbnav("G1 Adherence Report", $action, "vw_g1_app_data",

```

```

282     $col, $order, $limit,
283     "select * from vw_g1_app_data");
284 }
285
286 if ($action == "g2_mon")
287 {
288     if (!isset($col)) {
289         $col = "id";
290     }
291     if (!isset($order)) {
292         $order = "desc";
293     }
294     if (!isset($limit)) {
295         $limit = 10;
296     }
297     $select = dbnav("G2 Monitor Report", $action, "vw_g2_app_data",
298     $col, $order, $limit,
299     "select * from vw_g2_app_data");
300 }
301
302 if ($action == "g3_soc")
303 {
304     if (!isset($col)) {
305         $col = "id";
306     }
307     if (!isset($order)) {
308         $order = "desc";
309     }
310     if (!isset($limit)) {
311         $limit = 10;
312     }
313     $select = dbnav("G3 Social Report", $action, "vw_g3_app_data",
314     $col, $order, $limit,
315     "select * from vw_g3_app_data");
316 }
317
318
319
320 if ($action == "sms")
321 {
322     ?>
323 <html>
324 <body>
325
326         <font><font face="Verdana, Arial, Helvetica, sans-serif
327         " size="2"><b><!--Your
328         appointments for today are:--></b></font>
329
330         <p><iframe name="I1" src="https://celllife.eng.uct.ac
331         .za/sms/sendsms_current.php/" width="700" height
332         ="500">
333         Your browser does not support inline frames or is
334         currently configured not to display inline frames
335         .</iframe></p>
336
337         <font><font face="Verdana, Arial, Helvetica, sans-serif
338         " size="2"><b><!--Your
339         appointments for today are:--></b></font>
340
341 </body>
342 </html>
343
344     <?
345 }
346 if ($action == "smsr")
347 {
348     ?>

```

```

349 <html>
350 <body>
351
352         <font><font face="Verdana, Arial, Helvetica, sans-serif
           " size="2"><b><!--Your
353         appointments for today are:--></b></font>
354
355         <p><iframe name="I1" src="https://celllife.eng.uct.ac
356         .za/sms_logs/sms_reports.htm" width="700" height=
           "500">
357         Your browser does not support inline frames or is
           currently configured not to display inline frames
           .</iframe></p>
358
359         <font><font face="Verdana, Arial, Helvetica, sans-serif
           " size="2"><b><!--Your
360         appointments for today are:--></b></font>
361
362
363
364
365 </body>
366 </html>
367     <?
368 }
369 if ($action == "coun")
370 {
371     // select the default column to order by
372     if (!isset($col)) {
373         $col = "id";
374     }
375     if (!isset($order)) {
376         $order = "desc";
377     }
378     if (!isset($limit)) {
379         $limit = 20;
380     }
381
382     $select = dbnav("Counsellor List", $action, "vw_counsellor",
383         $col, $order, $limit,
384         "select * from vw_counsellor");
385     ?>
386 <html>
387 </body>
388 </html>
389     <?
390 }
391 ?>
392     </td>
393 </tr>
394 </table>
395 </tr>
396 </table>
397 </tr>
398 </table>
399 </body>
400 </html>
401

```

Sample of sendsms_current.php

This file allows outwards SMS through the Kannel GSM interface. The original file developed by Kannel and then customised for use with the Cell-Life system.

```

1 <html>

```


APPENDIX A. PROGRAMMING CODE

```
2 <head>
3 <title>Celllife Server SMS Message Sender</title>
4 </head>
5 <body bgcolor="#C0C0C0" text="#000000">
6
7 <?php
8 include("config.inc");
9 include("functions.inc");
10
11 if ($submit)
12 {
13     echo "Sending the SMS Text message <b>\'$text\'</b> to the phone <b>$to</b>
14         >...<br>\n";
15     $URL = "/cgi-bin/sendsms?username=".USERNAME."&password=".PASSWORD."&from=".
16         GLOBAL_SENDER."&to=$to&text=".urlencode($text);
17     http_send($URL,SENDSMS_PORT);
18     echo "<address><a href=\'$PHP_SELF\'>Back to Send SMS</a></address>\n";
19 } else {
20     ?>
21     <p>
22     <font face="Verdana, Arial, Helvetica, sans-serif" size="4" color="#0000FF">
23     <h3>Celllife Server SMS Message Sender</h3>
24     <form name="sendsms" method="post" action="<?php echo '$PHP_SELF' ?>">
25         <font face="Verdana, Arial, Helvetica, sans-serif" size="1" color="
26             #000000">
27
28     <tr>
29         <td width="50%">
30             <b>
31             <font face="Verdana, Arial, Helvetica, sans-serif" size="1" color="
32                 #000000">
33             Please choose to SMS:</font></b></td>
34     </tr>
35     <tr>
36         <td width="50%"><b>
37             <font face="Verdana, Arial, Helvetica, sans-serif" size
38                 ="1">
39             Celllife Counsellor / Admin / Director : </font></b>&
40             nbsp;<select size="1" name="to">
41             <option value="0824204829">Cell-Life Samir (Admin)</option>
42             <option value="0829404349">Cell-Life Ulrike</option>
43             <option value="0829736646">Cell-Life Jevon</option>
44             <option value="0724818888">Cell-Life Jalal</option>
45             <option value="0824858154">Cell-Life Dirk</option>
46             <option value="0825096699">N1G - SIS LULU</option>
47             <option value="0726037964">N2G(SiemensA35) - ?</option>
48             <option value="0825094740">N3G - CATHERINE</option>
49             <option value="0727073822">N4G - FLORA</option>
50             <option value="0727073829">N5G - NONTSIKELELO</option>
51             <option value="0723450916">N6G - NOMSA ROSE</option>
52             <option value="0826351480">N7G - PAMELA</option>
53             <option value="0723482020">N8G - MTETELELI</option>
54             <option value="0825041822">N9G - NOBAFUNDI</option>
55             <option value="0825030023">N10G - THEMBEKA</option>
56             <option value="0828113714">N11G - NOMA-ROM</option>
57             <option value="0723440715">N12G - SINDISWA</option>
58             <option value="0723489610">N13G - LETTIE</option>
59             <option value="0822615708">N14G - AYANDA</option>
60             <option value="0726029470">N15G - NOMUNTUNGQASE</option>
61
62         </select></td>
63         <td width="50%"><b>
64             <font face="Verdana, Arial, Helvetica, sans-serif" size
65                 ="1" color="#FF0000">
66             Please Note! This service is immediate and through our
67             Celllife server cellphone number (072 106 8793) and
68             costs
```

```

66             80c peak (8am - 8pm) and 30c off-peak
67             (8pm - 8am) per sms.</font></b><b>
68             <br>
69             <font face="Verdana, Arial, Helvetica, sans-serif" size="1">Enter your
70             message:</font></b></td>
71 </tr>
72
73
74
75 <br>
76 <textarea cols="40" rows="4" name="text"></textarea>
77 </p>
78
79 <tr>
80     <td width="50%">
81
82             <p> <b>
83             <font face="Verdana, Arial, Helvetica, sans-serif"
84             size="1" color="#FF0000">
85             NB: Your maximum message length is 160 characters.
86             The
87             above text box is this exact size. Please do not
88             exceed the message length. </font></b></p>
89             </td>
90 </tr>
91
92 <input type="submit" value="SEND SMS" name="submit">
93 <input type="reset" value="Reset">
94 <br>
95 </form>
96
97 <?php
98 }
99 ?>
100
101 <p>
102 </p>
103 <hr>
104 </tr>
105 </table>
106 </body>
107 </html>

```

A.3 SQL

The following code are samples of SQL commands used to when developing tables for a new WIG menu application. The raw data is inserted into *g2_app_data*. The index of this controlled by the sequence *g2_app_data_id_seq*. Test data is inserted to be sure all values and variables work correctly. Then a lookup table is created to give the raw data value. This is based upon the programming variable method used in WML. of how tables and views are made with lookup table! Finally a the view table is created by cross referencing multiple tables including the raw data, the lookup table and other relevant tables. The final view table is queried and displayed in the web user login.

```

1 CREATE SEQUENCE "g2_app_data_id_seq" start 1 increment 1 maxvalue
  9223372036854775807 minvalue 1 cache 1;
2 REVOKE ALL on "g2_app_data_id_seq" from public;

```

APPENDIX A. PROGRAMMING CODE

```
3 grant ALL on "g2_app_data_id_seq" to "samir";
4 grant ALL on "g2_app_data_id_seq" to "www";
5 grant ALL on "g2_app_data_id_seq" to "celllife";
6
7 CREATE TABLE "g2_app_data" (
8   "id" integer DEFAULT nextval('g2_app_data_id_seq'::text) NOT NULL,
9   "person_id" integer NOT NULL,
10  "symptom1" integer NOT NULL,
11  "s1_severity" integer NOT NULL,
12  "symptom2" integer NOT NULL,
13  "s2_severity" integer NOT NULL,
14  "symptom3" integer NOT NULL,
15  "s3_severity" integer NOT NULL,
16  "symptom_other" char(25) NOT NULL,
17  "month" integer NOT NULL,
18  "day" integer NOT NULL,
19  "time_am_pm" char(2) NOT NULL,
20  "alert" char(1) NOT NULL,
21  "visit_type" char(1) NOT NULL,
22  "at_home" char(1) NOT NULL,
23  "pill_count" char(1) NOT NULL,
24  "time" integer NOT NULL,
25  "cellphone_id" integer NOT NULL,
26  Constraint "g2_app_data_pkey" Primary Key ("id")
27 );
28
29 grant ALL on "g2_app_data" to "samir";
30 grant ALL on "g2_app_data" to "www";
31 grant ALL on "g2_app_data" to "celllife";
32
33 INSERT INTO g2_app_data (person_id, symptom1, s1_severity, symptom2,
34   s2_severity, symptom3, s3_severity, symptom_other, month, day, time_am_pm
35   , alert, visit_type, at_home, pill_count, time, cellphone_id) values
36   (1,2,3,4,5,6,7,8,9,0,1,2,3,4,5,6,7);
37
38 CREATE TABLE "g2_lookup" (
39   "id" integer,
40   "symptom" char(10) NOT NULL,
41   "severity" char(10) NOT NULL,
42   "month" char(10) NOT NULL,
43   "visit_id" char(1) NOT NULL,
44   "visit_type" char(10) NOT NULL
45 );
46
47 REVOKE ALL on "g2_lookup" from public;
48 grant ALL on "g2_lookup" to "samir";
49 grant ALL on "g2_lookup" to "www";
50
51 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
52   values (1,'Abdomen P','Mild','Jan','S','Surprised');
53 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
54   values (2,'Vomiting','Moderate','Feb','E','Expected');
55 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
56   values (3,'Rash','Severe','Mar',0,0);
57 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
58   values (4,'Fever','V Severe','Apr',0,0);
59 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
60   values (5,'Other','Not Grade','May',0,0);
61 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
62   values (6,0,0,'Jun',0,0);
63 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
64   values (7,0,0,'Jul',0,0);
65 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
66   values (8,0,0,'Aug',0,0);
67 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
68   values (9,0,0,'Sep',0,0);
69 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
70   values (10,0,0,'Oct',0,0);
71 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
72   values (11,0,0,'Nov',0,0);
73 INSERT INTO g2_lookup (id,symptom,severity,month,visit_id,visit_type)
74   values (12,0,0,'Dec',0,0);
```


APPENDIX A. PROGRAMMING CODE

[illegible]

```
95
96 </form>
97
98 </body>
99 </html>
```

A.5 UNIX Shell Scripts

The following script is used to query the Kannel logs file of SMS communication and create a text file summary of all SMSs received by the Cell-Life system. This text file is then made available online with an HTML page. A screen shot of this page in a web browser can be found in Appendix D.2.

```
1 cd /
2 cd /home/www/html/sms_logs
3 rm totals.txt
4 echo ' ' >> totals ;
5
6 echo 'CELLLIFE SYSTEM' >> totals ;
7 echo '-----' >> totals ;
8 echo ' ' >> totals ;
9
10 echo 'SMS TOTALS: 2004' >> totals ;
11 echo '-----' >> totals ;
12 echo ' Jan:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-01' | wc -l >> totals ;
13 echo ' Feb:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-02' | wc -l >> totals ;
14 echo ' Mar:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-03' | wc -l >> totals ;
15 echo ' Apr:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-04' | wc -l >> totals ;
16 echo ' May:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-05' | wc -l >> totals ;
17 echo ' Jun:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-06' | wc -l >> totals ;
18 echo ' Jul:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-07' | wc -l >> totals ;
19 echo ' Aug:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-08' | wc -l >> totals ;
20 echo ' Sep:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-09' | wc -l >> totals ;
21 echo ' Oct:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-10' | wc -l >> totals ;
22 echo ' Nov:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-11' | wc -l >> totals ;
23 echo ' Dec:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2004-12' | wc -l >> totals
24
25
26 echo 'SMS TOTALS: 2003' >> totals ;
27 echo '-----' >> totals ;
28 echo ' Jan:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-01' | wc -l >> totals ;
29 echo ' Feb:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-02' | wc -l >> totals ;
30 echo ' Mar:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-03' | wc -l >> totals ;
31 echo ' Apr:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-04' | wc -l >> totals ;
32 echo ' May:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-05' | wc -l >> totals ;
```

```

33 echo ' Jun:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-06' | wc -l >> totals ;
34 echo ' Jul:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-07' | wc -l >> totals ;
35 echo ' Aug:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-08' | wc -l >> totals ;
36 echo ' Sep:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-09' | wc -l >> totals ;
37 echo ' Oct:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-10' | wc -l >> totals ;
38 echo ' Nov:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-11' | wc -l >> totals ;
39 echo ' Dec:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2003-12' | wc -l >> totals
40
41 echo 'SMS TOTALS: 2002' >> totals ;
42 echo '-----' >> totals ;
43 echo ' Jul:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-07' | wc -l >> totals ;
44 echo ' Aug:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-08' | wc -l >> totals ;
45 echo ' Sep:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-09' | wc -l >> totals ;
46 echo ' Oct:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-10' | wc -l >> totals ;
47 echo ' Nov:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-11' | wc -l >> totals ;
48 echo ' Dec:' >> totals ; cat /var/log/kannel/smsbox.access.log | grep '
    2002-12' | wc -l >> totals ;
49 echo ' ' >> totals ;
50
51 cp totals totals.txt
52 rm totals

```

A.6 WIG

A.6.1 WML Code

WML V1.1 DTD

```

1  <!--
2  Wireless Markup Language (WML) Document Type Definition.
3
4  Copyright Wireless Application Protocol
5  Forum Ltd., 1998,1999.
6
7      All rights reserved.
8
9  WML is an XML language.  Typical usage:
10  <?xml version="1.0"?>
11  <!DOCTYPE wml PUBLIC "-//WAPFORUM//DTD WML 1.1//EN"
12      "http://www.wapforum.org/DTD/wml_1.1.xml">
13  <wml>
14  ...
15  </wml>
16
17  Terms and conditions of use are
18  available from the Wireless
19  Application Protocol Forum Ltd. web site at
20  http://www.wapforum.org/docs/copyright.htm.
21  -->
22  <!ENTITY % length "CDATA">

```

```

23     <!-- [0-9]+ for pixels or [0-9]+%"
24         for percentage length -->
25 <!ENTITY % vdata "CDATA">
26     <!-- attribute value possibly containing
27         variable references -->
28 <!ENTITY % HREF "%vdata;">
29     <!-- URI, URL or URN designating a
30         hypertext node. May contain variable references -->
31 <!ENTITY % boolean "(true|false)">
32 <!ENTITY % number "NMTOKEN">
33     <!-- a number, with format [0-9]+ -->
34 <!ENTITY % coreattrs "id ID #IMPLIED
35                     class CDATA #IMPLIED">
36
37 <!ENTITY % emph
38     "em | strong | b | i | u | big | small">
39 <!ENTITY % layout "br">
40
41 <!ENTITY % text "#PCDATA | %emph;">
42
43 <!-- flow covers "card-level" elements,
44     such as text and images -->
45 <!ENTITY % flow
46     "%text; | %layout; | img | anchor | a | table">
47
48 <!-- Task types -->
49 <!ENTITY % task "go | prev | noop | refresh">
50
51 <!-- Navigation and event elements -->
52 <!ENTITY % navelmts "do | onevent">
53
54 <!--===== Decks and Cards =====>
55
56 <!ELEMENT wml ( head?, template?, card+ )>
57 <!ATTLIST wml
58     xml:lang NMTOKEN #IMPLIED
59     %coreattrs;
60     >
61
62 <!-- card intrinsic events -->
63 <!ENTITY % cardev
64     "onenterforward %HREF; #IMPLIED
65     onenterbackward %HREF; #IMPLIED
66     ontimer %HREF; #IMPLIED"
67     >
68
69 <!-- card field types -->
70 <!ENTITY % fields
71     "%flow; | input | select | fieldset">
72
73 <!ELEMENT card (onevent*, timer?, (do | p)*)>
74 <!ATTLIST card
75     title %vdata; #IMPLIED
76     newcontext %boolean; "false"
77     ordered %boolean; "true"
78     xml:lang NMTOKEN #IMPLIED
79     %cardev;
80     %coreattrs;
81     >
82
83 <!--===== Event Bindings =====>
84
85 <!ELEMENT do (%task;)>
86 <!ATTLIST do
87     type CDATA #REQUIRED
88     label %vdata; #IMPLIED
89     name NMTOKEN #IMPLIED
90     optional %boolean; "false"
91     xml:lang NMTOKEN #IMPLIED
92     %coreattrs;
93     >
94
95 <!ELEMENT onevent (%task;)>

```


APPENDIX A. PROGRAMMING CODE

```

96 <!--ATTLIST onevent
97     type          CDATA          #REQUIRED
98     %coreattrs;
99 >
100
101 <!--===== Deck-level declarations =====>
102
103 <!--ELEMENT head ( access | meta )*>
104 <!--ATTLIST head
105     %coreattrs;
106 >
107
108 <!--ELEMENT template (%navelmts;)*>
109 <!--ATTLIST template
110     %cardev;
111     %coreattrs;
112 >
113
114 <!--ELEMENT access EMPTY>
115 <!--ATTLIST access
116     domain          CDATA          #IMPLIED
117     path             CDATA          #IMPLIED
118     %coreattrs;
119 >
120
121 <!--ELEMENT meta EMPTY>
122 <!--ATTLIST meta
123     http-equiv       CDATA          #IMPLIED
124     name              CDATA          #IMPLIED
125     forua             %boolean;     #IMPLIED
126     content           CDATA          #REQUIRED
127     scheme            CDATA          #IMPLIED
128     %coreattrs;
129 >
130
131 <!--===== Tasks =====>
132
133 <!--ELEMENT go (postfield | setvar)*>
134 <!--ATTLIST go
135     href              %HREF;         #REQUIRED
136     sendreferer       %boolean;      "false"
137     method            (post|get)     "get"
138     accept-charset    CDATA          #IMPLIED
139     %coreattrs;
140 >
141
142 <!--ELEMENT prev (setvar)*>
143 <!--ATTLIST prev
144     %coreattrs;
145 >
146
147 <!--ELEMENT refresh (setvar)*>
148 <!--ATTLIST refresh
149     %coreattrs;
150 >
151
152 <!--ELEMENT noop EMPTY>
153 <!--ATTLIST noop
154     %coreattrs;
155 >
156
157 <!--===== postfield =====>
158
159 <!--ELEMENT postfield EMPTY>
160 <!--ATTLIST postfield
161     name              %vdata;        #REQUIRED
162     value             %vdata;        #REQUIRED
163     %coreattrs;
164 >
165
166 <!--===== variables =====>
167
168 <!--ELEMENT setvar EMPTY>

```

APPENDIX A. PROGRAMMING CODE

```

169 <!ATTLIST setvar
170     name      %vdata;          #REQUIRED
171     value      %vdata;          #REQUIRED
172     %coreattrs;
173 >
174
175 <!--===== Card Fields =====>
176
177 <!ELEMENT select (optgroup|option)+>
178 <!ATTLIST select
179     title      %vdata;          #IMPLIED
180     name        NMTOKEN          #IMPLIED
181     value       %vdata;          #IMPLIED
182     iname       NMTOKEN          #IMPLIED
183     ivalue      %vdata;          #IMPLIED
184     multiple    %boolean;        "false"
185     tabindex    %number;         #IMPLIED
186     xml:lang    NMTOKEN          #IMPLIED
187     %coreattrs;
188 >
189
190 <!ELEMENT optgroup (optgroup|option)+ >
191 <!ATTLIST optgroup
192     title      %vdata;          #IMPLIED
193     xml:lang    NMTOKEN          #IMPLIED
194     %coreattrs;
195 >
196
197 <!ELEMENT option (#PCDATA | onevent)*>
198 <!ATTLIST option
199     value       %vdata;          #IMPLIED
200     title       %vdata;          #IMPLIED
201     onpick      %HREF;          #IMPLIED
202     xml:lang    NMTOKEN          #IMPLIED
203     %coreattrs;
204 >
205
206 <!ELEMENT input EMPTY>
207 <!ATTLIST input
208     name        NMTOKEN          #REQUIRED
209     type        (text|password)  "text"
210     value       %vdata;          #IMPLIED
211     format      CDATA            #IMPLIED
212     emptyok     %boolean;        "false"
213     size        %number;         #IMPLIED
214     maxlength   %number;         #IMPLIED
215     tabindex    %number;         #IMPLIED
216     title       %vdata;          #IMPLIED
217     xml:lang    NMTOKEN          #IMPLIED
218     %coreattrs;
219 >
220
221 <!ELEMENT fieldset (%fields; | do)* >
222 <!ATTLIST fieldset
223     title      %vdata;          #IMPLIED
224     xml:lang    NMTOKEN          #IMPLIED
225     %coreattrs;
226 >
227
228 <!ELEMENT timer EMPTY>
229 <!ATTLIST timer
230     name        NMTOKEN          #IMPLIED
231     value       %vdata;          #REQUIRED
232     %coreattrs;
233 >
234
235 <!--===== Images =====>
236
237 <!ENTITY % IAlign "(top|middle|bottom)" >
238
239 <!ELEMENT img EMPTY>
240 <!ATTLIST img
241     alt         %vdata;          #REQUIRED

```

```

242     src          %HREF;          #REQUIRED
243     localsrc     %vdata;         #IMPLIED
244     vspace       %length;        "0"
245     hspace       %length;        "0"
246     align        %IAAlign;       "bottom"
247     height       %length;        #IMPLIED
248     width        %length;        #IMPLIED
249     xml:lang     NMTOKEN         #IMPLIED
250     %coreattrs;
251 >
252
253 <!--===== Anchor =====>
254
255 <!ELEMENT anchor
256 ( #PCDATA | br | img | go | prev | refresh )*>
257 <!ATTLIST anchor
258     title        %vdata;         #IMPLIED
259     xml:lang     NMTOKEN         #IMPLIED
260     %coreattrs;
261 >
262
263 <!ELEMENT a ( #PCDATA | br | img )*>
264 <!ATTLIST a
265     href         %HREF;          #REQUIRED
266     title        %vdata;         #IMPLIED
267     xml:lang     NMTOKEN         #IMPLIED
268     %coreattrs;
269 >
270
271 <!--===== Tables =====>
272
273 <!ELEMENT table (tr)+>
274 <!ATTLIST table
275     title        %vdata;         #IMPLIED
276     align        CDATA           #IMPLIED
277     columns      %number;        #REQUIRED
278     xml:lang     NMTOKEN         #IMPLIED
279     %coreattrs;
280 >
281
282 <!ELEMENT tr (td)+>
283 <!ATTLIST tr
284     %coreattrs;
285 >
286
287 <!ELEMENT td
288 ( %text; | %layout; | img | anchor | a )*>
289 <!ATTLIST td
290     xml:lang     NMTOKEN         #IMPLIED
291     %coreattrs;
292 >
293
294 <!--== Text layout and line breaks ==-->
295
296 <!ELEMENT em      (%flow;)*>
297 <!ATTLIST em
298     xml:lang     NMTOKEN         #IMPLIED
299     %coreattrs;
300 >
301
302 <!ELEMENT strong  (%flow;)*>
303 <!ATTLIST strong
304     xml:lang     NMTOKEN         #IMPLIED
305     %coreattrs;
306 >
307
308 <!ELEMENT b       (%flow;)*>
309 <!ATTLIST b
310     xml:lang     NMTOKEN         #IMPLIED
311     %coreattrs;
312 >
313
314 <!ELEMENT i       (%flow;)*>

```

```

315 <!-- ATTLIST i
316     xml:lang          NMTOKEN          #IMPLIED
317     %coreattrs;
318 >
319
320 <!-- ELEMENT u          (%flow;)*>
321 <!-- ATTLIST u
322     xml:lang          NMTOKEN          #IMPLIED
323     %coreattrs;
324 >
325
326 <!-- ELEMENT big        (%flow;)*>
327 <!-- ATTLIST big
328     xml:lang          NMTOKEN          #IMPLIED
329     %coreattrs;
330 >
331
332 <!-- ELEMENT small      (%flow;)*>
333 <!-- ATTLIST small
334     xml:lang          NMTOKEN          #IMPLIED
335     %coreattrs;
336 >
337
338 <!-- ENTITY % TAlign "(left|right|center)">
339 <!-- ENTITY % WrapMode "(wrap|nowrap)" >
340 <!-- ELEMENT p (%fields; | do)*>
341 <!-- ATTLIST p
342     align              %TAlign;        "left"
343     mode               %WrapMode;      #IMPLIED
344     xml:lang           NMTOKEN          #IMPLIED
345     %coreattrs;
346 >
347
348 <!-- ELEMENT br EMPTY>
349 <!-- ATTLIST br
350     xml:lang          NMTOKEN          #IMPLIED
351     %coreattrs;
352 >
353
354 <!-- ENTITY quot "&#34;">
355 <!-- quotation mark -->
356 <!-- ENTITY amp "&#38;#38;">
357 <!-- ampersand -->
358 <!-- ENTITY apos "&#39;">
359 <!-- apostrophe -->
360 <!-- ENTITY lt "&#38;#60;">
361 <!-- less than -->
362 <!-- ENTITY gt "&#62;">
363 <!-- greater than -->
364 <!-- ENTITY nbsp "&#160;">
365 <!-- non-breaking space -->
366 <!-- ENTITY shy "&#173;">
367 <!-- soft hyphen (discretionary hyphen) -->
368
369 <!--
370 Copyright Wireless Application Protocol
371 Forum Ltd., 1998,1999.
372 All rights reserved.
373 -->

```

Cell-Life Original Menu

```

1 #Cell-Life Original Guglethu Menu
2 <wml>
3   <card id="MAIN">
4     <select title="Please choose service" name="TYPE">
5       <option value="adh" onpick="#C1">Adherence</option>
6       <option value="sym" onpick="#C2">Symptom</option>

```

APPENDIX A. PROGRAMMING CODE

```

7         <option value="apt" onpick="#C3">Appointment</option>
8         <option value="alt" onpick="#C4">Alert</option>
9         <option value="vis" onpick="#C5">Visit</option>
10      </select>
11    </card>
12    <card id="C1">
13      <input format="*N" name="ID" title="Patient Number:" maxlength="10"
14        emptyok="false"/>
15      <select title="Drugs:" name="DRUG">
16        <option value="nev" onclick="#PL">nevirapine</option>
17        <option value="efa" onclick="#PL">efavirenz</option>
18        <option value="lop" onclick="#PL">lopinavir</option>
19        <option value="nel" onclick="#PL">nelfinavir</option>
20        <option value="saq" onclick="#PL">saquinavir</option>
21        <option value="rit" onclick="#PL">ritonavir</option>
22        <option onclick="#DR2">..more</option>
23      </select>
24    </card>
25    <card id="DR2">
26      <select title="More Drugs:" name="DRUG">
27        <option value="azt" onclick="#PL">AZT</option>
28        <option value="3tc" onclick="#PL">3TC</option>
29        <option value="com" onclick="#PL">combivir</option>
30        <option value="ddi" onclick="#PL">ddI</option>
31        <option value="d4t" onclick="#PL">d4T</option>
32        <option value="aba" onclick="#PL">abacavir</option>
33        <option onclick="#C1">..prev</option>
34      </select>
35    </card>
36    <card id="PL">
37      <input format="*N" name="PC" title="Pills Left in bottle:" maxlength="4"
38        emptyok="false"/>
39      <input format="*N" name="1DY" title="Doses taken yesterday:"
40        maxlength="1" emptyok="false"/>
41      <input format="*N" name="2DY" title="Doses taken 2 days ago:"
42        maxlength="1" emptyok="false"/>
43      <input format="*N" name="3DY" title="Doses taken 3 days ago:"
44        maxlength="1" emptyok="false"/>
45      Submit drug adherence
46
47      <go href="http://c.o#wigSendSM('$(TYPE) $(ID):$(DRUG):$(PC):$(1DY)
48        :$(2DY):$(3DY) ', , , +27721068793, )"/>
49
50    </card>
51    <card id="C2">
52      <input format="*N" name="ID" title="Patient Number:" maxlength="10" emptyok
53        ="false"/>
54      <select title="symptom:" name="SYM">
55        <option value="abd">abdomen pain</option>
56        <option value="vom">vomiting</option>
57        <option value="ras">rash</option>
58        <option value="fev">fever</option>
59        <option onclick="#OTH">other</option>
60      </select>
61      <go href="#GRADE"/>
62    </card>
63    <card id="OTH">
64      <input format="text" name="SYM" title="Other Symptom:" maxlength="25" />
65      <go href="#GRADE"/>
66    </card>
67    <card id="GRADE">
68      <select title="Grade" name="GD">
69        <option value="1">mild</option>
70        <option value="2">moderate</option>
71        <option value="3">severe</option>
72        <option value="4">very severe</option>
73        <option value="5">not gradable</option>
74      </select>
75      Submit Symptom
76
77      <go href="http://c.o#wigSendSM('$(TYPE) $(ID):$(SYM):$(GD)
78        ', , , +27721068793, )"/>
79
80    </card>
81    <card id="C3">

```

APPENDIX A. PROGRAMMING CODE

```
72     <input format="*N" name="ID" title="Patient Number:" maxlength="10"
       emptyok="false"/>
73 <input format="*N" name="MONTH" title="Month:" maxlength="2" emptyok="false"
   " />
74     <input format="*N" name="DAY" title="Day of month:" maxlength="2" emptyok=
       "false" />
75     <select title="prefered time:" name="TIME">
76         <option value="8">8am</option>
77         <option value="9">9am</option>
78         <option value="10">10am</option>
79         <option value="11">11am</option>
80         <option value="12">12pm</option>
81         <option value="13">1pm</option>
82         <option value="14">2pm</option>
83         <option value="15">3pm</option>
84     </select>
85     Request an appointment
86
87     <go href="http://c.o#wigSendSM('$(TYPE) $(ID):$(DAY):$(MONTH):$(
       TIME)',,,+27721068793,)" />
88 </card>
89 <card id="C4">
90     <input format="*N" name="ID" title="Patient Number:" maxlength="10"
       emptyok="false"/>
91     Get immediate attention
92
93     <go href="http://c.o#wigSendSM('$(TYPE) $(ID)',,,+27721068793,)" />
94 </card>
95     <card id="C5">
96         <input format="*N" name="ID" title="Patient Number:" maxlength="10"
           emptyok="false"/>
97         <select title="Patient was:" name="AVA">
98             <option value="1">available</option>
99             <option value="0">unavailable</option>
100         </select>
101         Submit routine visit check
102
103         <go href="http://c.o#wigSendSM('$(TYPE) $(ID):$(AVA)
           ',,,+27721068793,)" />
104     </card>
105 </wml>
```

Cell-Life Adherence Menu (G1) V1.4

```
1 #Cell-Life Adherence Menu (G1) V1.4
2 <!DOCTYPE wml SYSTEM "C:\Documents and Settings\Samir\Desktop\Current_Work\
   Cell-Life Work\Team Work\WIG_Work\Lastest\wml_1_1.dtd">
3 <wml>
4
5 <card id="STARTUP">
6     <setvar name = "TYPE" value = "G1"/>
7     <input format = "*N" name = "ID" title = "ID No:" maxlength = "10" emptyok =
       "false"/>
8
9     <setvar name = "D1" value = "0"/>
10    <setvar name = "D1_PL" value = "0"/>
11    <setvar name = "D1_1DY" value = "0"/>
12    <setvar name = "D1_2DY" value = "0"/>
13    <setvar name = "D1_3DY" value = "0"/>
14
15    <setvar name = "D2" value = "0"/>
16    <setvar name = "D2_PL" value = "0"/>
17    <setvar name = "D2_1DY" value = "0"/>
18    <setvar name = "D2_2DY" value = "0"/>
19    <setvar name = "D2_3DY" value = "0"/>
20
21    <setvar name = "D3" value = "0"/>
22    <setvar name = "D3_PL" value = "0"/>
```

APPENDIX A. PROGRAMMING CODE

```

23     <setvar name = "D3_1DY" value = "0"/>
24     <setvar name = "D3_2DY" value = "0"/>
25     <setvar name = "D3_3DY" value = "0"/>
26
27     <setvar name = "MISSED_DOSE" value = "0"/>
28     <setvar name = "LOST" value = "0"/>
29     <setvar name = "DAMAGED" value = "0"/>
30     <setvar name = "PREGNANT" value = "0"/>
31     <setvar name = "SIDE_EFFECTS_RASH" value = "0"/>
32     <setvar name = "SIDE_EFFECTS_ABD" value = "0"/>
33     <setvar name = "SIDE_EFFECTS_PARAESTHESIA" value = "0"/>
34
35     <go href = "#MAIN_MENU"/>
36 </card>
37
38 <card id = "MAIN_MENU">
39     <select title = "">
40         <option onpick = "#MAIN_MENU">ADH MENU:</option>
41         <option onpick = "#ADHERENCE">Adh</option>
42         <option onpick = "#PROBLEMS">Adh Probs</option>
43         <option onpick = "#SUBMIT">Check</option>
44     </select>
45 </card>
46
47 <card id = "ADHERENCE">
48     <p>Drug:
49         1) Nevirapine
50         2) Efavirenz
51         3) Lopinavir
52         4) Nelfinavir
53         5) Saquinavir
54         6) Ritonavir
55         7) AZT
56         8) 3TC
57         9) Combivir
58         10) ddI
59         11) d4T
60         12) Abacavir
61     </p>
62     <input format = "*N" name = "D1" title = "D1?" maxlength = "2"
63         emptyok = "false"/>
64     <input format = "*N" name = "D1_PL" title = "# left?" maxlength = "2"
65         emptyok = "false"/>
66     <input format = "*N" name = "D1_1DY" title = "yest?" maxlength = "1"
67         emptyok = "false"/>
68     <input format = "*N" name = "D1_2DY" title = "2 days?" maxlength = "1"
69         emptyok = "false"/>
70     <input format = "*N" name = "D1_3DY" title = "3 days?" maxlength = "1"
71         emptyok = "false"/>
72
73     <input format = "*N" name = "D2" title = "D2?" maxlength = "2"
74         emptyok = "false"/>
75     <input format = "*N" name = "D2_PL" title = "# left?" maxlength = "2"
76         emptyok = "false"/>
77     <input format = "*N" name = "D2_1DY" title = "yest?" maxlength = "1"
78         emptyok = "false"/>
79     <input format = "*N" name = "D2_2DY" title = "2 days?" maxlength = "1"
80         emptyok = "false"/>
81     <input format = "*N" name = "D2_3DY" title = "3 days?" maxlength = "1"
82         emptyok = "false"/>
83
84     <input format = "*N" name = "D3" title = "D3?" maxlength = "2"
85         emptyok = "false"/>
86     <input format = "*N" name = "D3_PL" title = "# left?" maxlength = "2"
87         emptyok = "false"/>
88     <input format = "*N" name = "D3_1DY" title = "yest?" maxlength = "1"
89         emptyok = "false"/>
90     <input format = "*N" name = "D3_2DY" title = "2 days?" maxlength = "1"
91         emptyok = "false"/>
92     <input format = "*N" name = "D3_3DY" title = "3 days?" maxlength = "1"
93         emptyok = "false"/>
94
95     <go href = "#MAIN_MENU"/>
96 </card>

```

```

81
82 <card id = "PROBLEMS">
83     <select title = "">
84         <option onclick = "#PROBLEMS">Probs:</option>
85         <option onclick = "#MAIN_MENU">None</option>
86         <option onclick = "#MISSED_DOSE">Miss Dose</option>
87         <option onclick = "#LOST">Lost</option>
88         <option onclick = "#DAMAGED">Damage</option>
89         <option onclick = "#SIDE_EFFECTS">S/Effects</option>
90         <option onclick = "#PREGNANT">Preg</option>
91     </select>
92 </card>
93
94 <card id = "MISSED_DOSE">
95     <p>
96         <setvar name = "MISSED_DOSE" value = "Y"/>
97     </p>
98     <go href = "#ANOTHER_PROBLEM"/>
99 </card>
100
101 <card id = "LOST">
102     <p>
103         <setvar name = "LOST" value = "Y"/>
104     </p>
105     <go href = "#ANOTHER_PROBLEM"/>
106 </card>
107
108 <card id = "DAMAGED">
109     <p>
110         <setvar name = "DAMAGED" value = "Y"/>
111     </p>
112     <go href = "#ANOTHER_PROBLEM"/>
113 </card>
114
115 <card id = "SIDE_EFFECTS">
116     <select title="">
117         <option onclick = "#SIDE_EFFECTS">Side Eff:</option>
118         <option onclick = "#RASH">Rash</option>
119         <option onclick = "#ABD">Abd Pain</option>
120         <option onclick = "#PARAESTHESIA">Paraesthesia</option>
121     </select>
122 </card>
123
124 <card id = "PREGNANT">
125     <p>
126         <setvar name = "PREGNANT" value = "Y"/>
127     </p>
128     <go href = "#ANOTHER_PROBLEM"/>
129 </card>
130
131 <card id = "ANOTHER_PROBLEM">
132     <select title="">
133         <option onclick = "#ANOTHER_PROBLEM">Anthr Prob?</option>
134         <option onclick = "#PROBLEMS">Y</option>
135         <option onclick = "#MAIN_MENU">N</option>
136     </select>
137 </card>
138
139 <card id = "RASH">
140     <p>
141         <setvar name = "SIDE_EFFECTS_RASH" value = "Y"/>
142     </p>
143     <go href = "#ANOTHER_SIDE_EFFECT"/>
144 </card>
145
146 <card id = "ABD">
147     <p>
148         <setvar name = "SIDE_EFFECTS_ABD" value = "Y"/>
149     </p>
150     <go href = "#ANOTHER_SIDE_EFFECT"/>
151 </card>
152
153 <card id = "PARAESTHESIA">

```


APPENDIX A. PROGRAMMING CODE

```
154         <p>
155         <setvar name = "SIDE_EFFECTS_PARAESTHESIA" value = "Y"/>
156         </p>
157         <go href = "#ANOTHER_SIDE_EFFECT"/>
158     </card>
159
160     <card id = "ANOTHER_SIDE_EFFECT">
161         <select title = "">
162             <option onclick = "#ANOTHER_SIDE_EFFECT">Anthr SE?</option>
163             <option onclick = "#SIDE_EFFECTS">Y</option>
164             <option onclick = "#PROBLEMS">N</option>
165         </select>
166     </card>
167
168     <card id = "SUBMIT">
169         <select title = "">
170             <option onclick = "#SUBMIT">CHECK:</option>
171             <option onclick = "#ADH_SUBMIT">Data</option>
172             <option onclick = "#MAIN_MENU">BACK</option>
173             <option onclick = "#SEND">SEND!</option>
174             <option onclick = "#RESET">RESET</option>
175         </select>
176     </card>
177
178     <card id = "RESET">
179         <select title = "">
180             <option onclick = "#RESET">Are u sure?</option>
181             <option onclick = "#STARTUP">Y</option>
182             <option onclick = "#SUBMIT">N</option>
183         </select>
184     </card>
185
186     <card id = "ADH_SUBMIT">
187         <p>
188             ID No:$(ID)
189             $(D1):$(D1_PL):$(D1_1DY):$(D1_2DY):$(D1_3DY)
190             $(D2):$(D2_PL):$(D2_1DY):$(D2_2DY):$(D2_3DY)
191             $(D3):$(D3_PL):$(D3_1DY):$(D3_2DY):$(D3_3DY)
192             $(MISSED_DOSE):$(LOST):$(DAMAGED):$(PREGNANT):$(SIDE_EFFECTS_RASH)
193             $(SIDE_EFFECTS_ABD):$(SIDE_EFFECTS_PARAESTHESIA)
194         </p>
195         <go href = "#SUBMIT"/>
196     </card>
197
198     <card id = "SEND">
199         <go href = "http://c.o#wigSendSM('$(TYPE) :$(ID):$(D1):$(D1_PL):$(D1_1DY)
200             :$(D1_2DY):$(D1_3DY):$(D2):$(D2_PL):$(D2_1DY):$(D2_2DY):$(D2_3DY):$(
201             D3):$(D3_PL):$(D3_1DY):$(D3_2DY):$(D3_3DY):$(MISSED_DOSE):$(LOST):$(
202             DAMAGED):$(PREGNANT):$(SIDE_EFFECTS_RASH):$(SIDE_EFFECTS_ABD):$(
203             SIDE_EFFECTS_PARAESTHESIA)',,,+27721068793,)" />
204         <p>
205             Sent!
206         </p>
207     </card>
208 </wml>
```

Cell-Life Monitor Menu (G2) V1.4

```
1 #Cell-Life Monitor Menu (G1) V1.4
2 <!DOCTYPE wml SYSTEM "C:\Documents and Settings\Samir\Desktop\Current_Work\
   Cell-Life Work\Team Work\WIG_Work\Lastest\wml_1_1.dtd">
3 <wml>
4
5     <card id="STARTUP">
6         <setvar name = "TYPE" value = "G2"/>
7         <input format = "*N" name = "ID" title = "ID No:" maxlength = "10" emptyok =
           "false"/>
```

```

8
9      <setvar name = "SYMPTOM1" value = "0"/>
10     <setvar name = "S1_SEVERITY" value = "0"/>
11     <setvar name = "SYMPTOM2" value = "0"/>
12     <setvar name = "S2_SEVERITY" value = "0"/>
13     <setvar name = "SYMPTOM3" value = "0"/>
14     <setvar name = "S3_SEVERITY" value = "0"/>
15     <setvar name = "SYMPTOM_OTHER" value = "0"/>
16
17     <setvar name = "MONTH" value = "0"/>
18     <setvar name = "DAY" value = "0"/>
19     <setvar name = "TIME" value = "0"/>
20
21     <setvar name = "ALERT" value = "0"/>
22
23     <setvar name = "VISIT_TYPE" value = "0"/>
24     <setvar name = "AT_HOME" value = "0"/>
25     <setvar name = "PILL_COUNT" value = "0"/>
26     <go href = "#MAIN_MENU"/>
27 </card>
28
29 <card id="MAIN_MENU">
30     <select title = "">
31         <option onpick = "#MAIN_MENU">MON MENU:</option>
32         <option onpick = "#VISIT">Visit</option>
33         <option onpick = "#SYMPTOM">Symptom</option>
34         <option onpick = "#APPOINTMENT">Appointment</option>
35         <option onpick = "#ALERT">Alert</option>
36         <option onpick = "#SUBMIT">Check</option>
37     </select>
38 </card>
39
40 <card id = "SYMPTOM">
41     <p>Symptom:
42     0)None
43     1)Abdomen Pain
44     2)Vomiting
45     3)Rash
46     4)Fever
47     5)Other
48     </p>
49     <p>Severity:
50     1)Mild
51     2)Moderate
52     3)Severe
53     4)Very Severe
54     5)Not Gradable
55     </p>
56     <input format = "*N" name = "SYMPTOM1" title = "SYM1?" maxlength = "1"
57         " emptyok = "false"/>
58     <input format = "*N" name = "SYMPTOM2" title = "SYM2?" maxlength = "1"
59         " emptyok = "false"/>
60     <input format = "*N" name = "SYMPTOM3" title = "SYM3?" maxlength = "1"
61         " emptyok = "false"/>
62     <input format = "*N" name = "SYMPTOM_OTHER" title = "Other?"
63         " emptyok = "false"/>
64     <go href = "#MAIN_MENU"/>
65 </card>
66
67 <card id = "APPOINTMENT">
68     <input format = "*N" name = "MONTH" title = "Month:" maxlength = "2" emptyok =
69         "false" />
70     <input format = "*N" name = "DAY" title = "Day of month:" maxlength = "2" emptyok =
71         "false" />
72     <go href = "#TIME"/>
73 </card>

```

```

72 <card id = "TIME">
73   <select title="" name="TIME">
74     <option onclick = "#TIME">Time?</option>
75     <option value="am">am</option>
76     <option value="pm">pm</option>
77   </select>
78   <go href="#MAIN_MENU"/>
79 </card>
80
81 <card id = "ALERT">
82   <select title = "" name = "ALERT">
83     <option onclick = "#ALERT">Issue Alert?</option>
84     <option value = "Y">Y</option>
85     <option value = "N">N</option>
86   </select>
87   <go href="#MAIN_MENU"/>
88 </card>
89
90 <card id = "VISIT">
91   <select title="" name = "AT_HOME">
92     <option onclick = "#VISIT">Patient is:</option>
93     <option value = "Y">At Home</option>
94     <option value = "N" onclick = "#MAIN_MENU">Not At Home</option>
95   </select>
96   <go href="#VISIT_TYPE"/>
97 </card>
98
99 <card id = "VISIT_TYPE">
100   <select title="" name = "VISIT_TYPE">
101     <option onclick = "#VISIT_TYPE">Visit Type:</option>
102     <option value = "S">Surprised</option>
103     <option value = "E">Expected</option>
104   </select>
105   <go href="#PILL_COUNT"/>
106 </card>
107
108 <card id = "PILL_COUNT">
109   <select title="" name = "PILL_COUNT">
110     <option onclick = "#PILL_COUNT">P/Count?</option>
111     <option value = "Y">Y</option>
112     <option value = "N">N</option>
113   </select>
114   <go href="#MAIN_MENU"/>
115 </card>
116
117 <card id = "SUBMIT">
118   <select title = "">
119     <option onclick = "#SUBMIT">CHECK:</option>
120     <option onclick = "#VISIT_SUBMIT">Visit</option>
121     <option onclick = "#SYMPTOM_SUBMIT">Symptoms</option>
122     <option onclick = "#APPOINTMENT_SUBMIT">Apptmnt</option>
123     <option onclick = "#ALERT_SUBMIT">Alert</option>
124     <option onclick = "#MAIN_MENU">BACK</option>
125     <option onclick = "#SEND">SEND!</option>
126     <option onclick = "#RESET">RESET</option>
127   </select>
128 </card>
129
130 <card id = "RESET">
131   <select title = "">
132     <option onclick = "#RESET">Are u sure?</option>
133     <option onclick = "#STARTUP">Y</option>
134     <option onclick = "#SUBMIT">N</option>
135   </select>
136 </card>
137
138 <card id = "SYMPTOM_SUBMIT">
139   <p>
140     Symptom1:${SYMPTOM1}
141     Severity:${S1_SEVERITY}
142     Symptom2:${SYMPTOM2}
143     Severity:${S2_SEVERITY}
144     Symptom3:${SYMPTOM3}

```

```

145         Severity:$(S3_SEVERITY)
146         Other:$(SYMPTOM_OTHER)
147     </p>
148     <go href="#SUBMIT"/>
149 </card>
150
151 <card id = "APPOINTMENT_SUBMIT">
152 <p>
153     Month:$(MONTH)
154     Day:$(DAY)
155     Time:$(TIME)
156 </p>
157     <go href="#SUBMIT"/>
158 </card>
159
160 <card id = "ALERT_SUBMIT">
161 <p>
162     Alert:$(ALERT)
163 </p>
164     <go href="#SUBMIT"/>
165 </card>
166
167 <card id = "VISIT_SUBMIT">
168 <p>
169     ID No:$(ID)
170     Type:$(VISIT_TYPE)
171     At Home:$(AT_HOME)
172     Pill Count:$(PILL_COUNT)
173 </p>
174     <go href="#SUBMIT"/>
175 </card>
176
177 <card id = "SEND">
178 <go href="http://c.o#wigSendSM('$(TYPE) :$(ID):$(SYMPTOM1):$(S1_SEVERITY):$(
SYMPTOM2):$(S2_SEVERITY):$(SYMPTOM3):$(S3_SEVERITY):$(SYMPTOM_OTHER):$(
MONTH):$(DAY):$(TIME):$(ALERT):$(VISIT_TYPE):$(AT_HOME):$(PILL_COUNT)
',,,+27721068793,)" />
179 <p>
180     Sent!
181 </p>
182 </card>
183
184 </wml>

```

Cell-Life Social Menu (G2) V1.4

```

1 #Cell-Life Social Menu (G1) V1.4
2 <!DOCTYPE wml SYSTEM "C:\Documents and Settings\Samir\Desktop\Current_Work\
Cell-Life Work\Team Work\WIG_Work\Lastest\wml_1_1.dtd">
3 <wml>
4
5 <card id="STARTUP">
6     <setvar name = "TYPE" value = "G3"/>
7     <input format = "*N" name = "ID" title = "ID No:" maxlength = "10" emptyok =
"false"/>
8
9     <setvar name = "HOME_TYPE" value = "0"/>
10    <setvar name = "ELECTRICITY" value = "0"/>
11    <setvar name = "DEPENDENTS" value = "0"/>
12    <setvar name = "ROOMS" value = "0"/>
13    <setvar name = "ALL_PEOPLE" value = "0"/>
14    <setvar name = "RUNNING_WATER" value = "0"/>
15
16    <setvar name = "TELEPHONE" value = "0"/>
17    <setvar name = "TB_STATUS" value = "0"/>
18    <setvar name = "MONTH_IN" value = "0"/>
19    <setvar name = "DAY_IN" value = "0"/>
20    <setvar name = "MONTH_OUT" value = "0"/>

```

APPENDIX A. PROGRAMMING CODE

```
21     <setvar name = "DAY_OUT" value = "0"/>
22
23     <setvar name = "PCP" value = "0"/>
24     <setvar name = "DIARRHEA" value = "0"/>
25
26     <setvar name = "PNEUMONIA" value = "0"/>
27     <setvar name = "ALCOHOL" value = "0"/>
28     <setvar name = "OTHER_SUBST" value = "0"/>
29     <setvar name = "DG" value = "0"/>
30     <setvar name = "FOOD_MONEY" value = "0"/>
31     <setvar name = "RELATIONSHIP" value = "0"/>
32     <setvar name = "DISCLOSURE" value = "0"/>
33
34     <go href = "#MAIN_MENU"/>
35 </card>
36
37 <card id="MAIN_MENU">
38     <select title ="">
39         <option onpick = "#MAIN_MENU"> SOC MENU:</option>
40         <option onpick = "#PROBLEMS">Prob.</option>
41         <option onpick = "#HOME">Home</option>
42         <option onpick = "#HOSPITALISATION">Hosp.</option>
43         <option onpick = "#SUBMIT">Check</option>
44     </select>
45 </card>
46
47 <card id = "PROBLEMS">
48     <select title ="">
49         <option onpick = "#ALCOHOL">Alc</option>
50         <option onpick = "#OTHER_SUBST">Othr Sub</option>
51         <option onpick = "#DG">D/G</option>
52         <option onpick = "#FOOD_MONEY">Food $</option>
53         <option onpick = "#RELATIONSHIP">Relat</option>
54         <option onpick = "#DISCLOSURE">Disc</option>
55     </select>
56 </card>
57
58 <card id = "ALCOHOL">
59     <p>
60         <setvar name = "ALCOHOL" value = "Y"/>
61     </p>
62     <go href="#ANOTHER_PROBLEM"/>
63 </card>
64
65 <card id = "OTHER_SUBST">
66     <input format="text" name="OTHER_SUBST" title="Othr:" maxlength="25" />
67     <go href="#ANOTHER_PROBLEM"/>
68 </card>
69
70 <card id = "DG">
71     <p>
72         <setvar name = "DG" value = "Y"/>
73     </p>
74     <go href="#ANOTHER_PROBLEM"/>
75 </card>
76
77 <card id = "FOOD_MONEY">
78     <setvar name = "FOOD_MONEY" value = "Y"/>
79     <go href="#ANOTHER_PROBLEM"/>
80 </card>
81
82 <card id = "RELATIONSHIP">
83     <setvar name = "RELATIONSHIP" value = "Y"/>
84     <go href="#ANOTHER_PROBLEM"/>
85 </card>
86
87 <card id = "DISCLOSURE">
88     <setvar name = "DISCLOSURE" value = "Y"/>
89     <go href="#ANOTHER_PROBLEM"/>
90 </card>
91
92 <card id = "ANOTHER_PROBLEM">
93     <select title="">
```

APPENDIX A. PROGRAMMING CODE

```
94         <option onclick = "#ANOTHER_PROBLEM">Anthr Prb?</option>
95         <option onclick = "#PROBLEMS">Y</option>
96         <option onclick = "#MAIN_MENU">N</option>
97     </select>
98 </card>
99
100 <card id = "HOME">
101     <select title = "">
102         <option onpick = "#HOME">Home:</option>
103         <option onpick = "#HOME_TYPE">Type</option>
104         <option onpick = "#ELECTRICITY">Elec</option>
105         <option onpick = "#DEPENDENTS">Dep</option>
106         <option onpick = "#ROOMS">Rms</option>
107         <option onpick = "#ALL_PEOPLE">All ppl</option>
108         <option onpick = "#RUNNING_WATER">Water</option>
109         <option onpick = "#TELEPHONE">Cell #</option>
110     </select>
111 </card>
112
113 <card id = "HOME_TYPE">
114     <select title = "" name = "HOME_TYPE">
115         <option value = "inf" onpick = "#MORE">Inform</option>
116         <option value = "brk" onpick = "#MORE">Brck</option>
117     </select>
118 </card>
119
120 <card id = "ELECTRICITY">
121     <setvar name = "ELECTRICITY" value = "Y"/>
122     <go href="#MORE"/>
123 </card>
124
125 <card id = "DEPENDENTS">
126     <input format="*N" name="DEPENDENTS" title = "# of Depnd?" maxlength="2"
127         emptyok="false"/>
128     <go href = "#MORE"/>
129 </card>
130
131 <card id = "ROOMS">
132     <input format="*N" name="ROOMS" title = "# of rms?" maxlength="2" emptyok="
133         false"/>
134     <go href = "#MORE"/>
135 </card>
136
137 <card id = "ALL_PEOPLE">
138     <input format="*N" name="ALL_PEOPLE" title = "# of ppl?" maxlength="2"
139         emptyok="false"/>
140     <go href = "#MORE"/>
141 </card>
142
143 <card id = "RUNNING_WATER">
144     <setvar name = "RUNNING_WATER" value = "Y"/>
145     <go href="#MORE"/>
146 </card>
147
148 <card id = "TELEPHONE">
149     <input format="*N" name="TELEPHONE" title = "Cell #?" maxlength="10"
150         emptyok="false"/>
151     <go href = "#MORE"/>
152 </card>
153
154 <card id = "MORE">
155     <select title = "">
156         <option onclick = "#MORE">Anthr?</option>
157         <option onclick = "#HOME">Y</option>
158         <option onclick = "#MAIN_MENU">N</option>
159     </select>
160 </card>
161
162 <card id = "HOSPITALISATION">
163     <select title = "">
164         <option onpick = "#HOSPITALISATION">H:</option>
165         <option onpick = "#TB_STATUS">TB Stat</option>
166         <option onpick = "#HOSPITAL">Hspital</option>
```

APPENDIX A. PROGRAMMING CODE

```
163         <option onpick = "#OPP_INFECTION">Infec</option>
164         <option onpick = "#MAIN_MENU">None</option>
165     </select>
166 </card>
167
168 <card id = "TB_STATUS">
169     <p>
170         <setvar name = "TB_STATUS" value = "Y"/>
171     </p>
172     <go href = "#ANOTHER_HOSPITALISATION"/>
173 </card>
174
175 <card id = "HOSPITAL">
176     <input format="*N" name="DAY_IN" title = "Day In?" maxlength="2" emptyok
177         ="false"/>
178     <input format="*N" name="MONTH_IN" title = "Mn In?" maxlength="2"
179         emptyok="false"/>
180     <input format="*N" name="DAY_OUT" title = "Day Out?" maxlength="2"
181         emptyok="false"/>
182     <input format="*N" name="MONTH_OUT" title = "Mn Out?" maxlength="2"
183         emptyok="false"/>
184     <go href = "#ANOTHER_HOSPITALISATION"/>
185 </card>
186
187 <card id = "ANOTHER_HOSPITALISATION">
188     <select title="">
189         <option onclick = "#ANOTHER_HOSPITALISATION">Anthr ?</option>
190         <option onclick = "#HOSPITALISATION">Y</option>
191         <option onclick = "#MAIN_MENU">N</option>
192     </select>
193 </card>
194
195 <card id = "OPP_INFECTION">
196     <select title="">
197         <option onpick = "#PCP">PCP</option>
198         <option onpick = "#DIARRHEA">Diarr</option>
199         <option onpick = "#PNEUMONIA">Pneu</option>
200     </select>
201 </card>
202
203 <card id = "PCP">
204     <p>
205         <setvar name = "PCP" value = "Y"/>
206     </p>
207     <go href = "#ANOTHER_OPP_INFECTION"/>
208 </card>
209
210 <card id = "DIARRHEA">
211     <p>
212         <setvar name = "DIARRHEA" value = "Y"/>
213     </p>
214     <go href = "#ANOTHER_OPP_INFECTION"/>
215 </card>
216
217 <card id = "PNEUMONIA">
218     <p>
219         <setvar name = "PNEUMONIA" value = "Y"/>
220     </p>
221     <go href = "#ANOTHER_OPP_INFECTION"/>
222 </card>
223
224 <card id = "ANOTHER_OPP_INFECTION">
225     <select title="">
226         <option onclick = "#ANOTHER_OPP_INFECTION">Anthr?</option>
227         <option onclick = "#OPP_INFECTION">Y</option>
228         <option onclick = "#MAIN_MENU">N</option>
229     </select>
230 </card>
231
232 <card id = "SUBMIT">
233     <select title="">
```

```

232         <option onpick = "#SUBMIT">CHECK:</option>
233         <option onpick = "#SUBMIT_HOSPITALISATION">Data</option>
234         <option onpick = "#MAIN_MENU">BACK</option>
235         <option onpick = "#SEND">SEND!</option>
236         <option onpick = "#RESET">RESET</option>
237     </select>
238 </card>
239
240 <card id = "RESET">
241     <select title = "">
242         <option onpick = "#RESET">Are U sure?</option>
243         <option onpick = "#STARTUP">Y</option>
244         <option onpick = "#SUBMIT">N</option>
245     </select>
246 </card>
247
248 <card id = "SUBMIT_HOSPITALISATION">
249     <p>
250         ID No:$(ID)
251         $(HOME_TYPE):$(ELECTRICITY):$(DEPENDENTS):$(ROOMS)
252         $(ALL_PEOPLE):$(RUNNING_WATER):$(TELEPHONE):$(TB_STATUS)
253         $(MONTH_IN):$(DAY_IN):$(MONTH_OUT):$(DAY_OUT)
254         $(PCP):$(DIARRHEA):$(PNEUMONIA):$(ALCOHOL)
255         $(OTHER_SUBST):$(DG):$(FOOD_MONEY):$(RELATIONSHIP):$(DISCLOSURE)
256     </p>
257     <go href = "#SUBMIT"/>
258 </card>
259 <card id = "SEND">
260     <go href="http://c.o#wigSendSM('$(TYPE) :$(ID):$(HOME_TYPE):$(ELECTRICITY)
        :$(DEPENDENTS):$(ROOMS):$(ALL_PEOPLE):$(RUNNING_WATER):$(TELEPHONE):
        $(TB_STATUS):$(MONTH_IN):$(DAY_IN):$(MONTH_OUT):$(DAY_OUT):$(PCP):$(
        DIARRHEA):$(PNEUMONIA):$(ALCOHOL):$(OTHER_SUBST):$(DG):$(FOOD_MONEY):
        $(RELATIONSHIP):$(DISCLOSURE)',,,+27721068793,)" />
261     <p>
262         Sent!
263     </p>
264 </card>
265
266 </wml>

```

A.6.2 WML Programming Reference Guide

```

1  Cell-Life WLM Programming Reference Guide
2  by S Anand, M Parker, D de Jager
3
4
5  WML Coding Format
6
7  1. Standardise DOCTYPE format i.e. All use one DTD
8
9
10 2. Declaration of variables
11
12 a. Lower Case Descriptive
13 All descriptive names of variables should be in lower case, separating words
    with underscores.
14
15 Example :
16 A variable named home type would be declared as home_type (? Upper case
17
18 b. Upper Case Coding Tags
19 All tags are in upper case (?)
20
21 c. Upper Case Cards
22 All card names are declared in upper case, with an underscore separating
    words. Each card name if referenced from a menu option, should have the
    corresponding name.
23

```


APPENDIX A. PROGRAMMING CODE

24 Example :

25 A card named SYMPTOM , referencing the option symptom would be declared as follows:

26 <option onpick = #SYMPTOM >Symptom</option>

27

28 d. Variable Referencing

29 A variable referencing guide is to be developed based upon alphanumeric tags to cover all possible implemented variables, based up the following format: A00. one alpha character (CAPS or small) with two decimal digits catering for 66924 possible variables. The only options that will not follow this format are:

30 0 = No or Blank, 1 =Yes

31 The standard format should follow this example:

32 m01 , m02 , m12 , for Months: Jan, Feb, Dec.

33 Over time a complete standardised document of variable references is to be developed.

34

35 e. Consistency using onpick

36 Since two methods can be used to indicate if an option has been selected i.e. onpick and onclick, consistency issues may arise. It was decided to use onpick in all cases.

37

38 f. Non-Variable Text Shortening

39 In the event that option strings need to be shortened, the following guidelines should be adhered to :

40

41 i. ALL words are consistent in a deck and all other decks on the phone.

42

43 Example :

44

45 If the word symptoms has been shortened to smptoms in one instance in a card, all other cards in the deck assumes this name as well as all other decks on the phone.

46

47

48 ii. Every pass on shortening a name, first removes a vowel from the front of the word, except the first letter of the word (in the event it is a vowel). In the case of the removal of all vowels, consonants will be removed from the back.

49

50 Example :

51

52 If the word Adherence needs to be shortened, the first pass would remove a vowel. Since the first letter is an A , it will be skipped and the result would be Adhrence .

53

54 iii. A word is not shortened twice, until all other words have had a turn in shortening. In this manner, there is not an excess amount of shortened vs no-shortened words in the deck.

55

56 3. Indentation

57 The <wml> and <card> keywords are the only to align next to the margin. Any nesting of <syntax> keywords thereafter, are to be indented, with its contents further indented. A corresponding </syntax> keyword if used on a new line, is to be aligned along the same margin setting as its counterpart.

58

59 Example :

60

61 <wml>

62 <card id = MAIN_MENU >

63 <select name = VISIT_TYPE >

64 <option onpick = #VISIT > Visit</option>

65 </select>

66 </card>

67 </wml>

68

69

70 4. Commenting

71 All cards are to be commented with the <!--> syntax. The commenting will precede the card, explaining its purpose and any notices that should be accounted for.

72

```
73 Pitfall Check List
74
75 1. Ensure variable initialisation at beginning
76 Every variable that is used within the body of the code MUST have itself
    first declared and initialised to 0 at the beginning.
77
78 2. Be aware of depth of loops
79 Loops in the menu structures should not be nested since it creates confusion
    to the user.
80
81 3. Cannot use <br> or <p>
82 Even though the WAC DTD specifies the use of these syntax keywords, they do
    not work on the Vodacom network and should not be used in code.
83
84 4. Ensure there are no spaces between $ and closing parenthesis in outgoing
    SMS
85
86
87 5. Variable to variable copying does not work
88
89
90 6. All variables must be sent in SMS
91
92
93 7. There should be a space and not a colon between $(TYPE) and $(ID)
94
95 Cellular Phone and SIM Procedures
96
97 All cellphones are to undergo the following procedure:
98
99 1. The phones serial number, associated SIM number should be logged into the
    asset register
100 2. The message center number for SMSing must be initialized, otherwise WIG
    will register errors.
101
102
103 All SIM cards are to undergo the following procedure:
104
105 1. The SIM number, ICCID number, PUK and PIN numbers are to be entered into
    the asset register
106 2. The SIM needs to be logged as a Cell-Life phone, by registering it on the
    website as well as enabling permanent
107 Location Based Services.
```

A.7 Firewall Rules

The following is sample of some of the IPFW rules implemented on the Cell-Life server with the support and advise of K Gajjar. All IP numbers have been falsified.

```
1 #Primary IP address : x.y.z.92
2
3 #flush everything else
4 -f flush
5
6 #Safety net
7 add 00001 allow ip from any to any
8
9 #1000-Generic Rules / spoofing
10 add 01000 check-state
11 add 01100 allow ip from x.y.z.92 to any
12 add 01001 pass all from any to any via lo0
13 add 01002 deny all from any to 127.0.0.0/8
14 add 01003 deny all from 127.0.0.0/8 to any
```

```

15
16 #2000-stateful rules, established bits, fragments, etc
17 add 02000 allow tcp from x.y.z.92 to any setup keep-state via de0
18 add 02001 allow udp from x.y.z.92 to any keep-state via de0
19 add 02010 allow icmp from any to x.y.z.92 icmptypes 0,3,4,11 via de0
20 add 02011 allow icmp from x.y.z.92 to any icmptypes 3,4,8,11 via de0
21
22
23 #3000-management access
24 #Allow my machine in on emergency port when stateful rules are full
25 add 03000 allow tcp from 196.30.158.245 to x.y.z.92 15000 via de0
26 add 03001 allow tcp from x.y.z.92 15000 to 196.30.158.245 established via de0
27 #Proceed with other rules
28 add 03002 allow tcp from 196.30.158.245 to x.y.z.92 22 setup via de0 limit
    src-addr 10
29
30 add 03100 allow tcp from x.y.001.114 to x.y.z.92 22 setup via de0 limit src-
    addr 10
31 add 03200 allow tcp from x.y.002.112 to x.y.z.92 22 setup via de0 limit src-
    addr 10
32 add 03300 allow tcp from x.y.003.122 to x.y.z.92 22 setup via de0 limit src-
    addr 10
33 add 03400 allow tcp from x.y.004.106 to x.y.z.92 22 setup via de0 limit src-
    addr 10
34
35 #4000-public services
36 add 04000 allow tcp from any to x.y.z.92 25 setup via de0 limit src-addr 50
37 add 04100 allow tcp from any to x.y.z.92 80 setup via de0 limit src-addr 1000
38 add 04200 allow tcp from any to x.y.z.92 443 setup via de0 limit src-addr
    1000
39 add 04300 allow tcp from any to x.y.z.92 993 setup via de0 limit src-addr 50
40 add 04400 allow tcp from any to x.y.z.92 995 setup via de0 limit src-addr 50
41 add 04500 allow tcp from any to x.y.z.92 113 setup via de0 limit src-addr 50
42 add 04600 allow tcp from any to x.y.z.92 465 setup via de0 limit src-addr 50
43
44 #5000-vpn services
45 #add 05000 allow tcp from any to x.y.z.92 1723 setup via de0
46 #add 05100 allow ip from 192.168.0.1 to 192.168.0.0/29 via ng*
47 #add 05200 allow ip from 192.168.0.0/29 to 192.168.0.1 via ng*
48 #add 05300 allow gre from any to x.y.z.92 via de0
49
50 #6000-deny all
51 add 06000 deny ip from any to x.y.z.92
52 add 06001 deny log ip from any to any
53 add 06100 deny all from any to any
54
55 #remove safety net
56 del 00001

```

A.8 Kannel Settings

The following is a sample of the Kannel GSM interface configuration. All services, scripts, IPs, passwords have been falsified.

```

1 #
2 # THIS IS A SAMPLE CONFIGURATION FOR SMS KANNEL
3 #
4 # It is run like this:
5 #
6 # 1% test/fakesmsc -p 10000 -i 1 -m 100 "123 345 nop"
7 # 2% gw/bearerbox gw/smskannel.conf
8 # 3% gw/smsbox gw/smskannel.conf
9 #
10 # ..as all 3 commands in separate shells (or screen sessions)
11 #

```

APPENDIX A. PROGRAMMING CODE

```
12 # For any modifications to this file, see Kannel User Guide
13 # If that does not help, send email to devel@kannel.org
14 #
15 # Kalle Marjola May 2000
16 #
17
18 group = core
19 admin-port = 12345
20 smsbox-port = 12346
21 admin-password = abc
22 status-password = deg
23 log-file = "/var/log/kannel/kannel.log"
24 log-level = 0
25 box-deny-ip = "*. *.*.*"
26 box-allow-ip = "127.0.0.1"
27 #admin-deny-ip = ""
28 #admin-allow-ip = ""
29 unified-prefix = "0,0"
30 access-log = "/var/log/kannel/access.log"
31
32 group = modems
33 id = falcom
34 name = "Falcom"
35 detect-string = "Falcom"
36 #no-smsc = true
37
38 group = smsc
39 smsc = at2
40 #smsc = at
41 modemtype = falcom
42 device = /dev/cuaa1
43 pin =1234
44 speed = 9600
45 #retry = 1
46 #keepalive = 60
47 #my-number = 072xxx1234
48 #sms-center = 0829119
49 sim-buffering = 1
50
51 group = smsbox
52 bearerbox-host = localhost
53 sendsms-port = 54321
54 global-sender = 0829129
55 sendsms-chars = "0123456789 +-"
56 log-file = "/var/log/kannel/smsbox.log"
57 log-level = 0
58 access-log = "/var/log/kannel/smsbox.access.log"
59
60 group = sms-service
61 keyword = nop
62 text = "You asked nothing and I did it!"
63
64 group = sms-service
65 keyword = ABC
66 url = "http://137.x.y.003/cgi-bin/cape_gugs_ABC.cgi?sender=%p&message=%r"
67 omit-empty = 1
68
69 group = sms-service
70 keyword = DEF
71 url = "http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%p&message=%r"
72 omit-empty = 1
73
74 group = sms-service
75 keyword = GHI
76 url = "http://137.x.y.003/cgi-bin/cape_gugs_GHI.cgi?sender=%p&message=%r"
77 omit-empty = 1
78
79 group = sendsms-user
80 username = abc123
81 password = 123abc
```

A.9 Log Files

The following is a sample of the *smsbox.access.log* of the Kannel GSM interface. All IPs and scripts have been falsified.

```

1 2004-08-27 14:12:42 send-SMS request added - sender:tester:0999666666
    127.0.0.1 target:0723450916 request: 'Nomsa, you are extremely quiet, Sis
    Elizabeth does not have a report about you what's up Sis Lulu'
2 2004-08-28 14:34:58 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A60%3A2%3A2%3A0%3A0%3A0%3A0%3A0%3A0%3A08%3A26%3Apm%3A0%3AS%3AY%3AN'
    reply: 200 '<< successful >>'
3 2004-08-28 14:52:32 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A485%3A3%3A2%3A0%3A0%3A0%3A0%3A0%3A0%3A28%3A28%3Apm%3A0%3AE%3AY%3AN
    ' reply: 200 '<< successful >>'
4 2004-08-28 14:55:39 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A449%3A5%3A3%3A0%3A0%3A0%3A0%3A0%3A0%3A08%3A27%3Apm%3A0%3AS%3AY%3AN
    ' reply: 200 '<< successful >>'
5 2004-08-28 15:04:58 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A407%3A5%3A2%3A0%3A0%3A0%3A0%3A0%3A0%3A08%3A27%3Apm%3A0%3AS%3AY%3AN
    ' reply: 200 '<< successful >>'
6 2004-08-28 15:13:15 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A420%3A4%3A2%3A0%3A0%3A0%3A0%3A0%3A0%3A08%3A27%3Apm%3A0%3AS%3AY%3AN
    ' reply: 200 '<< successful >>'
7 2004-08-28 15:16:22 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A419%3A0%3A0%3A0%3A0%3A0%3A0%3A0%3A0%3A0%3A27%3A27%3Apm%3A0%3AS%3AY%3AN
    ' reply: 200 '<< successful >>'
    2004-08-28 15:20:31 SMS HTTP-request
    sender:+27825041822 request: '' url: 'http://137.x.y.003/cgi-bin/
    cape_gugs_DEF.cgi?sender=%2B27825041822&message=%3A437%3A5%3A2%3A0%3A0%3
    A0%3A0%3A0%3A08%3A26%3Aam%3A0%3AS%3AY%3AN' reply: 200 '<< successful >>'
8 2004-08-28 15:24:40 SMS HTTP-request sender:+27825041822 request: '' url: '
    http://137.x.y.003/cgi-bin/cape_gugs_DEF.cgi?sender=%2B27825041822&
    message=%3A99%3A5%3A1%3A0%3A0%3A0%3A0%3A0%3A0%3A08%3A28%3Aam%3A0%3AS%3AY%3AN'
    reply: 200 '<< successful >>'

```

The following is a sample of the *httpd.log* of the Apache web server. All IPs and scripts have been falsified.

```

1
2 137.x.y.003 - - [28/Aug/2004:15:16:22 +0200] "GET /cgi-bin/cape_gugs_DEF.cgi?
    sender=%2B27825041822&message=%3A419%3A0%3A0%3A
3 0%3A0%3A0%3A0%3A0%3A27%3A27%3Apm%3A0%3AS%3AY%3AN HTTP/1.1" 200 5
4 137.x.y.003 - - [28/Aug/2004:15:20:31 +0200] "GET /cgi-bin/cape_gugs_DEF.cgi?
    sender=%2B27825041822&message=%3A437%3A5%3A2%3A
5 0%3A0%3A0%3A0%3A0%3A08%3A26%3Aam%3A0%3AS%3AY%3AN HTTP/1.1" 200 5
6 137.x.y.003 - - [28/Aug/2004:15:24:40 +0200] "GET /cgi-bin/cape_gugs_DEF.cgi?
    sender=%2B27825041822&message=%3A99%3A5%3A1%3A0
7 %3A0%3A0%3A0%3A0%3A08%3A28%3Aam%3A0%3AS%3AY%3AN HTTP/1.1" 200 5
8 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /login.php HTTP/1.1" 200 3392
9 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /include/wickedstyle.css HTTP
    /1.1" 304 -
10 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /include/overlib.css HTTP/1.1
    " 304 -
11 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/logo1.gif HTTP/1.1"
    304 -
12 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/logo_vodacom.gif HTTP
    /1.1" 304 -
13 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/powerlogo.gif HTTP
    /1.1" 304 -
14 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/rectangle_power_perl.
    gif HTTP/1.1" 304 -

```

APPENDIX A. PROGRAMMING CODE

```
15 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /login.php?=PHPE9568F34-D428
-11d2-A769-00AA001ACF42 HTTP/1.1" 200 2974
16 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/kannel_logo.gif HTTP
/1.1" 304 -
17 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/apache_pb.gif HTTP
/1.1" 304 -
18 127.0.0.1 - - [28/Aug/2004:16:25:07 +0200] "GET /images/postgresql_final1.jpg
HTTP/1.1" 304 -
19 127.0.0.1 - - [28/Aug/2004:16:25:14 +0200] "POST /login.php HTTP/1.1" 302 5
20 127.0.0.1 - - [28/Aug/2004:16:25:14 +0200] "GET /index.php HTTP/1.1" 200
13247
21 127.0.0.1 - - [28/Aug/2004:16:25:14 +0200] "GET /include/clear.gif HTTP/1.1"
304 -
22 127.0.0.1 - - [28/Aug/2004:16:30:14 +0200] "GET /index.php?action=g1_adh HTTP
/1.1" 200 15689
23 127.0.0.1 - - [28/Aug/2004:16:44:42 +0200] "GET /index.php?action=home HTTP
/1.1" 200 13247
24 127.0.0.1 - - [28/Aug/2004:16:47:36 +0200] "GET /index.php?action=coun HTTP
/1.1" 200 13328
25 127.0.0.1 - - [28/Aug/2004:16:49:19 +0200] "GET /index.php?action=home HTTP
/1.1" 200 13247
26 137.x.y.119 - - [28/Aug/2004:16:58:07 +0200] "OPTIONS / HTTP/1.1" 200 -
27 127.0.0.1 - - [28/Aug/2004:17:23:35 +0200] "GET /sms/sendsms_current.php HTTP
/1.1" 200 3183
28 127.0.0.1 - - [28/Aug/2004:17:23:35 +0200] "GET /images/mail.gif HTTP/1.1"
200 1235
29 127.0.0.1 - - [28/Aug/2004:17:23:44 +0200] "GET /sms/smsfinal.htm HTTP/1.1"
200 4546
30 127.0.0.1 - - [28/Aug/2004:17:24:01 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
31 127.0.0.1 - - [28/Aug/2004:17:24:01 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
32 127.0.0.1 - - [28/Aug/2004:17:24:01 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
33 127.0.0.1 - - [28/Aug/2004:17:24:01 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
34 127.0.0.1 - - [28/Aug/2004:17:24:29 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
35 127.0.0.1 - - [28/Aug/2004:17:24:29 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
36 127.0.0.1 - - [28/Aug/2004:17:24:29 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
37 127.0.0.1 - - [28/Aug/2004:17:24:29 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
38 127.0.0.1 - - [28/Aug/2004:17:24:32 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
39 127.0.0.1 - - [28/Aug/2004:17:24:32 +0200] "GET /sms/fphover.class HTTP/1.1"
404 302
40 127.0.0.1 - - [28/Aug/2004:17:24:32 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
41 127.0.0.1 - - [28/Aug/2004:17:24:32 +0200] "GET /sms/fphover/class.class HTTP
/1.1" 404 308
42 127.0.0.1 - - [28/Aug/2004:18:34:37 +0200] "GET /index.php?action=smsr HTTP
/1.1" 302 5
43 127.0.0.1 - - [28/Aug/2004:18:34:37 +0200] "GET /login.php?reset=yes HTTP/1.1
" 200 3392
44 127.0.0.1 - - [28/Aug/2004:18:34:38 +0200] "GET /login.php?=PHPE9568F34-D428
-11d2-A769-00AA001ACF42 HTTP/1.1" 200 2974
45 127.0.0.1 - - [28/Aug/2004:18:34:53 +0200] "POST /login.php HTTP/1.1" 302 5
46 127.0.0.1 - - [28/Aug/2004:18:34:53 +0200] "GET /index.php HTTP/1.1" 200
13247
47 127.0.0.1 - - [28/Aug/2004:18:34:57 +0200] "GET /index.php?action=smsr HTTP
/1.1" 200 5122
48 127.0.0.1 - - [28/Aug/2004:18:34:57 +0200] "GET /sms_logs/sms_reports.htm
HTTP/1.1" 200 1493
49 127.0.0.1 - - [28/Aug/2004:18:36:46 +0200] "GET /sms_logs/sms_rep_gugs.htm
HTTP/1.1" 200 2760
50 127.0.0.1 - - [28/Aug/2004:18:36:52 +0200] "GET /sms_logs/totals.txt HTTP/1.1
" 200 590
51 137.x.y.58 - - [28/Aug/2004:19:05:19 +0200] "OPTIONS / HTTP/1.1" 200 -
52 137.x.y.92 - - [28/Aug/2004:19:15:44 +0200] "OPTIONS / HTTP/1.1" 200 -
53 66.194.6.80 - - [28/Aug/2004:20:07:22 +0200] "GET /brochure/home.html HTTP
/1.1" 200 384
```

```
54 137.x.y.119 - - [28/Aug/2004:20:29:42 +0200] "OPTIONS / HTTP/1.1" 200 -
55 137.x.y.68 - - [28/Aug/2004:22:11:42 +0200] "OPTIONS / HTTP/1.1" 200 -
56 137.x.y.68 - - [28/Aug/2004:22:12:27 +0200] "OPTIONS / HTTP/1.1" 200 -
57 127.0.0.1 - - [28/Aug/2004:22:28:16 +0200] "GET /index.php?action=smsr HTTP
    /1.1" 302 5
```

A.10 Java Script

The following is a sample of the Java scripts used to carry out concurrent HTTP server requests.

```
1  package www.tests;
2
3  import java.io.BufferedReader;
4  import java.io.IOException;
5  import java.io.InputStream;
6  import java.io.InputStreamReader;
7  import java.net.URL;
8  import java.net.URLConnection;
9  import java.util.Date;
10
11 import javax.net.ssl.HostnameVerifier;
12 import javax.net.ssl.HttpsURLConnection;
13 import javax.net.ssl.SSLContext;
14 import javax.net.ssl.SSLSession;
15 import javax.net.ssl.TrustManager;
16 import javax.net.ssl.X509TrustManager;
17
18 import org.apache.commons.httpclient.HttpClient;
19 import org.apache.commons.httpclient.HttpException;
20 import org.apache.commons.httpclient.methods.GetMethod;
21
22 public class WWWTest {
23
24     public static void main(String[] args) throws IOException {
25
26         /**
27          * Just change the following line to the HTTP request you
28          * wish to use
29          * and the integer for number of concurrent hits
30          */
31         String connection = "https://xxx.xxx.uct.ac.za/login.php";
32
33         int numberOfConcurrentHits = 100;
34
35         tm();
36
37         for (int i = 0; i < numberOfConcurrentHits; i++) {
38             WWWThread wt = new WWWThread(connection);
39         }
40
41     }
42
43     public static void newURLCon(String con) throws IOException {
44         Date sDate = new Date();
45         URL bulkSMS = new URL(con);
46         URLConnection bulkSMSConnection = bulkSMS.openConnection();
47         BufferedReader in = new BufferedReader(new InputStreamReader(
48             bulkSMSConnection.getInputStream()));
49
50         String inputLine;
51         String result = "";
52         while ((inputLine = in.readLine()) != null) {
53             result = result + inputLine;
```

APPENDIX A. PROGRAMMING CODE

```
54         // System.out.println(inputLine);
55     }
56
57     in.close();
58     Date eDate = new Date();
59     long ms = eDate.getTime() - sDate.getTime();
60
61     System.out.println("Called: " + con + ".In " + ms + "
62         milliseconds");
63     // System.out.println("Start Time:" + sDate + "End Date:" +
64         eDate);
65 }
66
67 public static void oldURLCon(String con) throws IOException {
68     int c;
69     URL celllife = new URL(con);
70     System.out.println("Open connection");
71     URLConnection clCon = celllife.openConnection();
72
73     // System.out.println(new Date(clCon.getDate()));
74     // System.out.println(clCon.getContentType());
75     // System.out.println(clCon.getExpiration());
76     // System.out.println(new Date(clCon.getLastModified()));
77     int length = clCon.getContentLength();
78     System.out.println("Close connection");
79     // System.out.println("" + length);
80     if (length > 0) {
81         System.out.println("-----CONTENT-----");
82         InputStream input = clCon.getInputStream();
83         int i = length;
84         while (((c = input.read()) != -1) && (--i > 0)) {
85             System.out.print((char) c);
86         }
87         input.close();
88     } else {
89         System.out.println("No Content Available");
90     }
91 }
92
93 public static void apacheCon(String con) {
94     Date sDate = new Date();
95     HttpClient httpclient = new HttpClient();
96     GetMethod httpget = new GetMethod(con);
97     try {
98         httpclient.executeMethod(httpget);
99
100         System.out.println(httpget.getStatusLine());
101     } catch (HttpException e) {
102         // TODO Auto-generated catch block
103         e.printStackTrace();
104     } catch (IOException e) {
105         // TODO Auto-generated catch block
106         e.printStackTrace();
107     } finally {
108         httpget.releaseConnection();
109     }
110     Date eDate = new Date();
111     long ms = eDate.getTime() - sDate.getTime();
112     System.out.println("Called: " + con + ".In " + ms + "
113         milliseconds");
114 }
115
116 public static void tm() {
117     // Create a trust manager that does not validate certificate
118     // chains
119     TrustManager[] trustAllCerts = new TrustManager[] { new
120         X509TrustManager() {
121             public java.security.cert.X509Certificate[]
122                 getAcceptedIssuers() {
123                 return null;
124             }
125         }
126     }
```


APPENDIX A. PROGRAMMING CODE

```
121         }
122
123         public void checkClientTrusted(
124             java.security.cert.X509Certificate[]
125                 certs, String authType) {
126
127         }
128
129         public void checkServerTrusted(
130             java.security.cert.X509Certificate[]
131                 certs, String authType) {
132
133         }
134     } };
135
136     // Install the all-trusting trust manager
137     try {
138         SSLContext sc = SSLContext.getInstance("SSL");
139         // Create empty HostnameVerifier
140         HostnameVerifier hv = new HostnameVerifier() {
141             public boolean verify(String urlHostName,
142                 SSLSession session) {
143                 // logger.info("Warning: URL Host: "+
144                     urlHostName+"
145                     // vs. "+session.getPeerHost());
146                 return true;
147             }
148         };
149
150         sc.init(null, trustAllCerts, new java.security.
151             SecureRandom());
152         HttpsURLConnection
153             .setDefaultSSLSocketFactory(sc.
154                 getSocketFactory());
155         HttpsURLConnection.setDefaultHostnameVerifier(hv);
156     } catch (Exception e) {
157     }
158 }
159
160 }
161
162 }
163
164 }
165
166 }
167
168 }
169
170 }
171
172 }
173
174 }
175
176 }
177
178 }
179
180 }
181
182 }
183
184 }
185
186 }
187
188 }
189
190 }
191
192 }
193
194 }
195
196 }
197
198 }
199
200 }
201
202 }
203
204 }
205
206 }
```

```
1 package www.tests;
2
3 import java.io.IOException;
4
5 public class WWWThread implements Runnable {
6     Thread t;
7
8     String connection;
9
10    public WWWThread(String con) {
11
12        t = new Thread(this, "WWW Thread: " + con);
13        this.connection = con;
14        //System.out.println("Child Thread: " + t);
15        t.start();
16    }
17
18    public void run() {
19        try {
20            WWWTest.newURLCon(connection);
21        } catch (IOException e) {
22            System.out.println("IO Error!");
23        }
24    }
25
26 }
```

A.11 WAC Screen Shot

The following are WIG Application Creator (WAC) screen shots the original Gugulethu Menu and the revised and improved Adherence Menu.

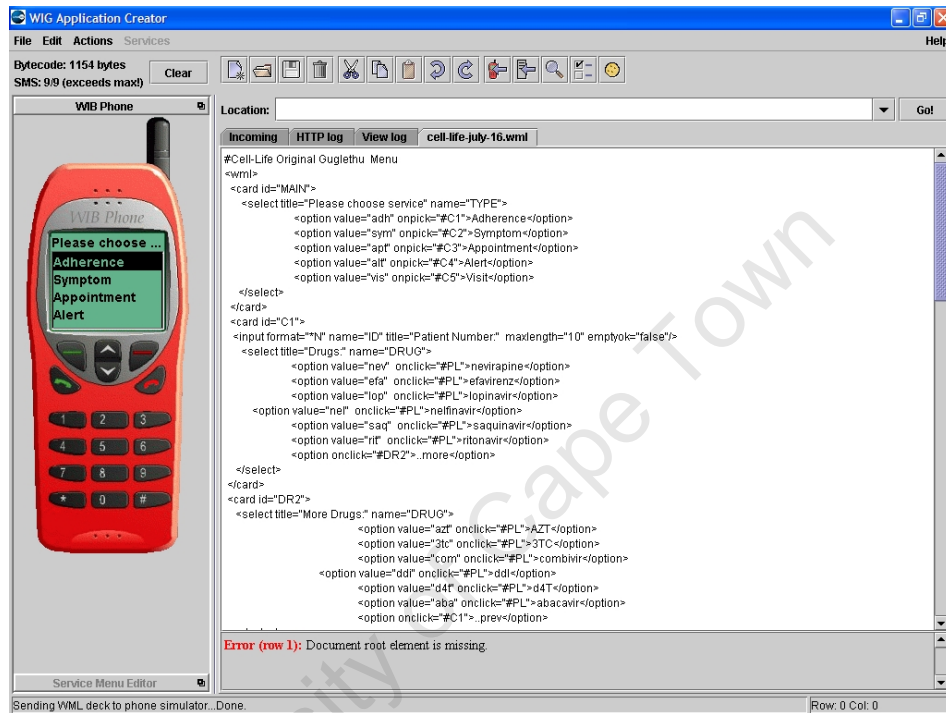


Figure A.1: WAC Screen Shot - Original Menu

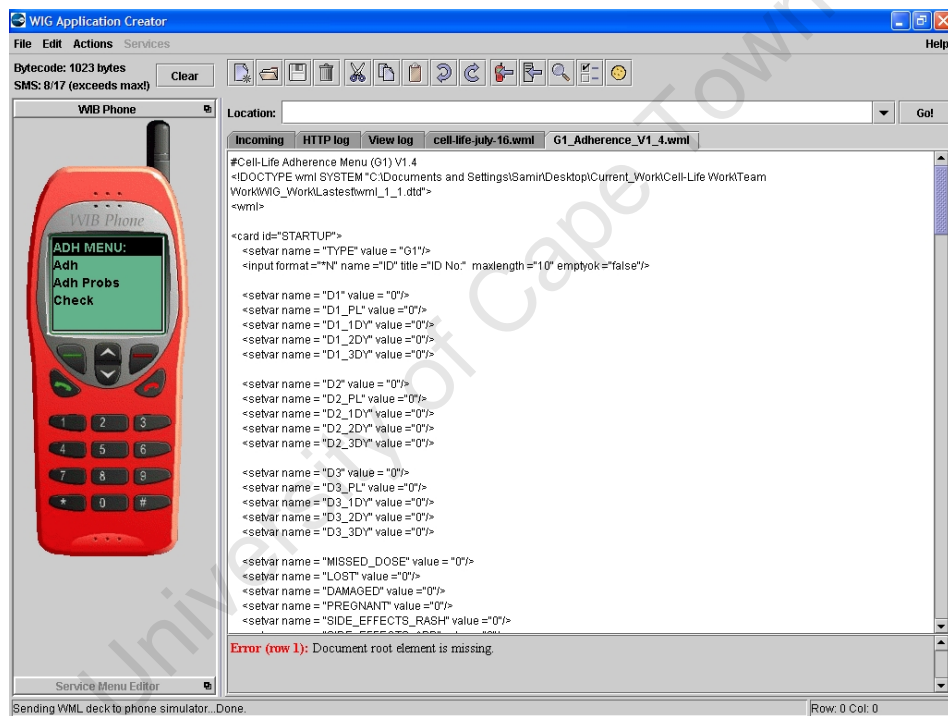


Figure A.2: WAC Screen Shot - The Adherence Menu

Appendix B

Testing Information

B.1 Usability Testing

B.1.1 Usability Testing Process

The following information was collected during the usability testing process from volunteer system testers, with specific tests being repeated for each tested application:

- Introduction and background to the system (cellphone and web applications)
- Participant background information (Age, Gender, Education Level, Computer Experience and Cellphone Experience)
- Participant consent
- Training and practise on each application prior to testing process
- Testing process was based upon carrying out a specific set of tasks followed by questionnaire evaluation
- HFT (Human Factor Test) questions
- SUS (System Usability Scale) questionnaire
- General user evaluation questionnaire

APPENDIX B. TESTING INFORMATION

Dear participant

Thank you very much for volunteering to carry out this usability test for MSc research by Samir Anand. Kindly please note the following points and complete the requested details followed by your signature.

Usability Testing Participant Details and Consent

- I am NOT being tested but the system (menus and software) is being tested.
- I have freely volunteered to participate in this experiment.
- I have been informed in advance what my tasks(s) will be and what procedures will be followed.
- I have been given the opportunity to ask questions and have had my questions answered to my satisfaction.
- I am aware that I have the right to withdraw consent and to discontinue participation at any time, without prejudice to my future treatment.
- My signature below may be taken as affirmation of all the above statements, it was given prior to my participation in this study.

Date _____ Signature _____

Figure B.1: Participant consent form

Participant Questionnaire: (MARK WITH AN "X")

Assign USER NO (3 digits)						
1. Age						
2. Gender	F	M				
3. Highest education level	Primary School	High School	Tertiary			
4. Have you used a computer before?	Y	N				
5. What is the level of your computer experience?	0 none	1 solitaire	2 word p	3 net/skyp	4 coding	5 expert
6. Have you used a cellphone before?	Y	N				
7. What is the level of your cellphone experience?	0 none	1 calls	2 sms	3 mms	4 gprs	5 ap/code

Figure B.2: Participant background information

B.2 System Usability Scale (SUS)

Figure B.3 is the SUS document consisting of a ten item scale evaluation questionnaire usability evaluation. Even though it has been developed mainly for web site evaluation, in this project it was used to evaluate web applications as well as cellphone menu applications. To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1,3,5,7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SUS out of 100.

	Strongly disagree						Strongly agree
1. I think that I would like to use this system frequently	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
2. I found the system unnecessarily complex	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
3. I thought the system was easy to use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
4. I think that I would need the support of a technical person to be able to use this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
5. I found the various functions in this system were well integrated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
6. I thought there was too much inconsistency in this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
7. I would imagine that most people would learn to use this system very quickly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
8. I found the system very cumbersome to use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
9. I felt very confident using the system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		
10. I needed to learn a lot of things before I could get going with this system	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
	1	2	3	4	5		

Figure B.3: The System Usability Scale (SUS) [7]

B.3 Human Factors Testing (HFT)

Human Factors Testing (HFT) was a set of questions set out to cover a number of human factors in the evaluation process through the use of the following:

- Time to learn?
- Time to complete tasks?
- Number and type of errors?
- Were you able to redo/correct actions?
- Are menus/displays consistent?
- Are menus/displays simple?
- Overall subjective satisfaction

B.3.1 Test Results

Cellphone Menu Applications

The usability testing process as described above was used for the testing of each cellphone menu application. Users were given a sample data card of two patient visits. All data had to be collected from the patient visit cards as the task. The test was repeated for each application with new patient visit cards each time. The following figures are a summary of the usability test answers as well as a table of database queried data reflecting a number of different types of error from the tests.

APPENDIX B. TESTING INFORMATION

		Current (System A1) PC													
User Information		Group A						Group B							
User No	3 digit #	104	107	111	112	114	115	105	106	108	109	110	113	Avg	
Age	years	22	32	25	26	23	26	30	24	27	23	26	27	25.9	
Gender	M/F	M	F	F	M	M	M	M	F	M	F	F	M		
Highest education (1.Primary, 2.High School, 3.Tertiary)	1/2/3	3	3	3	3	3	3	3	3	3	3	3	3	3	
Used a computer before	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
Level of computer experience	0 to 5	4	4	3	4	3	3	3	4	4	4	3	5	3.67	
Used a cellphone before	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
Level of cellphone experience	0 to 5	2	2	3	3	3	2	2	3	4	3	2	2	2.58	
English first language	Y/N	Y	N	N	Y	N	Y	Y	N	Y	N	Y	Y		
Human Factors Testing (HST)															
Time to train/learn	minutes	20	20	20	20	20	20	5	5	5	5	5	5	12.5	
Time to complete tasks	minutes	13	10	13	13	14	10	12	8	12	7	6	13	10.9	
Able to redo/correct actions?	Y/N/NA	NA	Y	Y	Y	Y	NA	N	Y	Y	N	Y	NA		
Are menus/displays consistent?	0 to 5	4	3	5	4	4	5	3	5	3	5	5	2	4	
Are menus/displays simple?	0 to 5	3	4	2	2	4	5	1	4	4	3	5	2	3.25	
Overall subjective satisfaction	0 to 5	4	4	4	4	4	5	1	4	3	4	4	3	3.67	
HFT Score		73%	73%	73%	67%	80%	100%	33%	87%	67%	80%	93%	47%	73%	
System Usability Scale (SUS)															
Q1	score	4	5	5	3	3	2	1	4	1	3	1	2		
Q2	score	2	2	2	2	3	3	2	1	4	3	1	3		
Q3	score	4	4	4	2	4	3	2	5	4	3	5	1		
Q4	score	1	2	1	2	4	1	2	1	1	2	1	1		
Q5	score	3	4	4	2	4	3	1	4	2	4	3	2		
Q6	score	2	1	1	2	2	3	2	1	4	1	1	3		
Q7	score	4	4	4	4	4	5	2	5	4	4	3	2		
Q8	score	2	2	1	3	4	5	2	1	5	4	4	5		
Q9	score	4	4	5	4	3	4	1	5	4	3	5	3		
Q10	score	2	3	1	1	2	1	3	1	4	3	1	2		
SUS Score		75%	78%	90%	63%	58%	60%	40%	95%	43%	60%	73%	40%	64%	

Table B.1: Usability testing results summary of current and new cellphone menu applications - Part1/2

Cellphone Menu Applications																										
Current (System A2) Cellphone																Current (System B) PC										
Group C			Group A						Group B																	
101	102	103	104	107	111	112	114	115	105	106	108	109	110	113	Avg	104	105	106	109	110	115	116	117	118	119	Avg
28	30	20	22	32	25	26	23	26	30	24	27	23	26	27	25.9	22	30	24	23	26	26	23	25	22	28	24.9
M	M	M	M	F	F	M	M	M	M	F	M	F	F	M		M	M	F	F	F	M	M	M	F	F	
2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2.8	3	3	3	3	3	3	3	3	3	3	3
N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
0	1	0	4	4	3	4	3	3	3	4	4	4	3	5	3	4	3	4	3	3	3	3	3	3	3	3.3
Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
2	3	2	2	2	3	3	3	2	2	3	4	3	2	2	2.5	2	2	3	3	2	2	2	3	2	2	2.3
N	N	N	Y	N	N	Y	N	Y	Y	N	Y	N	Y	Y		Y	Y	N	N	Y	Y	Y	N	Y	Y	
30	30	30	10	10	10	10	10	10	20	20	20	20	20	20	18	8	5	5	5	8	5	5	5	5	5	5.6
15	6	17	8	8	9	8	8	12	19	14	6	15	8	8	10.7	10	13	11	7	5	10	11	8	14	9	9.8
Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y		Y	Y	NA	N	Y	Y	Y	Y	Y	Y	
5	5	5	4	4	5	4	4	5	4	5	2	5	5	2	4.3	4	5	5	5	5	5	4	4	4	4	4.6
5	5	5	4	4	4	3	3	3	3	5	4	3	5	2	3.867	5	5	5	5	5	5	4	5	3	5	4.7
5	5	5	4	4	4	4	4	3	4	3	3	3	3	2	3.7	4	4	5	5	4	4	4	4	4	4	4.3
100%	100%	100%	80%	80%	87%	73%	67%	80%	67%	93%	60%	73%	87%	40%	79%	87%	93%	100%	100%	93%	93%	80%	87%	73%	100%	91%
5	5	5	4	4	5	3	2	3	4	5	3	4	1	2		2	4	5	5	1	3	5	1	3	4	
5	1	1	2	2	1	2	3	3	3	2	2	2	1	3		1	2	1	1	1	3	2	1	4	3	
5	5	5	5	4	4	3	4	3	3	5	4	3	5	2		4	4	5	5	5	4	4	4	3	4	
5	1	1	1	2	1	1	4	1	2	1	2	3	1	1		1	1	1	1	1	1	1	1	1	1	
5	5	3	3	4	4	4	4	4	4	5	3	4	3	3		2	3	5	5	4	3	4	4	3	3	
5	1	1	1	2	1	2	2	2	3	1	4	1	1	3		1	2	1	1	1	1	1	2	1	2	
5	5	5	4	4	4	5	4	5	4	4	4	3	3	4		5	5	5	5	3	5	5	5	4	5	
5	3	3	4	2	1	3	3	4	3	1	2	3	4	4		4	2	1	1	1	3	2	2	1	3	
5	4	5	3	4	5	4	2	4	2	4	4	2	5	3		4	4	5	5	5	4	4	5	5	4	
5	1	5	2	2	1	1	3	1	2	1	2	3	1	3		1	2	1	4	1	1	2	2	1	1	
50%	93%	80%	73%	75%	93%	75%	53%	70%	60%	93%	65%	60%	73%	50%	71%	73%	78%	100%	93%	83%	75%	88%	78%	75%	75%	82%

Table B.2: Usability testing results summary of current and new cellphone menu applications - Part2/2

APPENDIX B. TESTING INFORMATION

Id	Report Time	P #	C Name	C Phone	Sym 1	Sev 1	Sym 2	Sev 2	Sym 3	Sev 3	Month	Day	Time	Alert	At Home
11	2005-10-20 19:11:59+02	68	Test1	27729084232	Vomiting	V Severe	blank	blank	blank	blank	Mar	1	pm	Y	Y
15	2005-10-20 19:37:11+02	68	Test1	27729084232	Vomiting	V Severe	blank	blank	blank	blank	Mar	1	pm	Y	Y
23	2005-10-20 19:41:45+02	512	Test1	27729084232	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Feb	8	am	Y	Y
26	2005-10-21 14:45:23+02	178	Test1	27729084232	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	0	0	0	0	Y
27	2005-10-21 14:47:03+02	178	Test1	27729084232	blank	blank	blank	blank	blank	blank	Nov	7	am	0	Y
29	2005-10-21 14:50:49+02	301	Test1	27729084232	Rash	Severe	Vomiting	Severe	Fever	Mild	0	0	0	0	Y
30	2005-10-21 14:51:53+02	301	Test1	27729084232	blank	blank	blank	blank	blank	blank	0	0	0	0	Y
32	2005-10-21 14:52:36+02	301	Test1	27729084232	blank	blank	blank	blank	blank	blank	0	0	0	0	Y
6	2005-10-20 19:07:43+02	223	Test2	27729084271	Rash	Moderate	Other	Severe	Abdomen P	Mild	0	0	0	0	Y
7	2005-10-20 19:08:13+02	223	Test2	27729084271	blank	blank	blank	blank	blank	blank	Feb	12	am	0	Y
8	2005-10-20 19:09:09+02	223	Test2	27729084271	blank	blank	blank	blank	blank	blank	0	0	0	N	Y
12	2005-10-20 19:12:33+02	818	Test2	27729084271	blank	blank	blank	blank	blank	blank	0	0	0	0	Y
13	2005-10-20 19:13:27+02	818	Test2	27729084271	blank	blank	blank	blank	blank	blank	0	0	0	pm	Y
17	2005-10-20 19:38:01+02	512	Test2	27729084271	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Feb	8	am	N	Y
21	2005-10-20 19:41:33+02	720	Test2	27729084271	Fever	Moderate	Vomiting	Severe	Abdomen P	Moderate	May	12	pm	0	Y
10	2005-10-20 19:10:17+02	720	Test3	27729084514	Fever	Moderate	Vomiting	Severe	Abdomen P	Moderate	May	12	pm	0	Y
14	2005-10-20 19:17:11+02	178	Test3	27729084514	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Nov	7	am	0	Y
18	2005-10-20 19:38:07+02	178	Test3	27729084514	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Nov	7	am	N	Y
24	2005-10-20 19:42:45+02	68	Test3	27729084514	Vomiting	V Severe	blank	blank	blank	blank	Mar	1	pm	N	Y
2	2005-10-20 19:05:00+02	223	Test4	27729084295	Rash	Moderate	Abdomen P	Severe	Abdomen P	Mild	0	0	0	0	Y
5	2005-10-20 19:07:27+02	223	Test4	27729084295	blank	blank	blank	blank	blank	blank	Feb	12	am	0	Y
19	2005-10-20 19:39:31+02	178	Test4	27729084295	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Nov	7	am	0	Y
3	2005-10-20 19:05:07+02	445	Test5	27729084244	Vomiting	Not Grade	Rash	Severe	Fever	Severe	0	0	0	0	Y
4	2005-10-20 19:06:19+02	445	Test5	27729084244	blank	blank	blank	blank	blank	blank	May	1	am	N	Y
9	2005-10-20 19:09:41+02	818	Test5	27729084244	Fever	Severe	Other	Severe	Vomiting	Mild	Jun	6	pm	N	Y
16	2005-10-20 19:37:21+02	512	Test5	27729084244	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Feb	8	am	0	Y
20	2005-10-20 19:41:09+02	178	Test5	27729084244	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Nov	7	am	0	Y
25	2005-10-20 19:54:13+02	68	Test5	27729084244	Vomiting	V Severe	blank	blank	blank	blank	Mar	1	pm	Y	Y
31	2005-10-21 14:52:30+02	818	Test5	27729084244	Fever	Severe	Other	Severe	Vomiting	blank	Jun	6	pm	0	Y
33	2005-10-21 15:01:50+02	223	Test5	27729084244	Rash	Not Grade	Other	Severe	Abdomen P	Mild	Feb	12	am	0	Y
1	2005-10-20 19:03:23+02	445	Test6	27729084500	Vomiting	Not Grade	Rash	Severe	Severe	Severe	May	1	am	N	Y
22	2005-10-20 19:41:37+02	178	Test6	27729084500	Fever	Mild	Vomiting	Mild	Abdomen P	V Severe	Nov	7	pm	Y	Y

Table B.3: Data collection errors from the database for the new monitor application

	Id	Report Time	P #	C Name	C Phone	D1	D1 PC	D1 1d	D1 2d	D1 3d
2	9	2005-10-20 19:10:27+02	68	Test1	27729084232	Nevirapine	22	5	5	5
3	15	2005-10-20 19:35:05+02	68	Test1	27729084232	Nevirapine	22	5	5	5
11	29	2005-10-21 14:46:40+02	68	Test2	27729084271	Nevirapine	22	5	5	5
16	23	2005-10-20 19:40:09+02	68	Test3	27729084514	Nevirapine	22	5	5	5
25	26	2005-10-20 19:52:50+02	68	Test5	27729084244	Nevirapine	22	5	5	5
5	27	2005-10-21 14:41:56+02	178	Test1	27729084232	Nevirapine	12	2	2	2
13	11	2005-10-20 19:12:24+02	178	Test3	27729084514	Nevirapine	12	2	2	2
14	12	2005-10-20 19:15:28+02	178	Test3	27729084514	Nevirapine	12	2	2	2
15	16	2005-10-20 19:35:32+02	178	Test3	27729084514	Flavirapine	12	2	2	2
19	19	2005-10-20 19:37:27+02	178	Test4	27729084295	Nevirapine	12	2	2	2
23	21	2005-10-20 19:39:58+02	178	Test5	27729084244	Nevirapine	12	2	2	2
31	24	2005-10-20 19:40:15+02	178	Test6	27729084500	Nevirapine	12	2	2	2
7	4	2005-10-20 19:03:29+02	223	Test2	27729084271	Lopinavir	25	2	2	2
17	2	2005-10-20 19:00:27+02	223	Test4	27729084295	Lopinavir	25	2	2	2
27	31	2005-10-21 14:55:27+02	223	Test5	27729084244	Nevirapine	25	2	2	2
6	30	2005-10-21 14:49:44+02	301	Test1	27729084232	Nevirapine	25	1	1	1
18	13	2005-10-20 19:34:42+02	301	Test4	27729084295	Nevirapine	25	1	1	1
24	25	2005-10-20 19:48:18+02	301	Test5	27729084244	Nevirapine	25	1	1	1
30	14	2005-10-20 19:34:55+02	301	Test6	27729084500	Nevirapine	25	1	1	1
20	3	2005-10-20 19:03:04+02	445	Test5	27729084244	Nelfinavir	52	3	3	3
28	1	2005-10-20 18:59:43+02	445	Test6	27729084500	Nelfinavir	52	3	3	3
4	22	2005-10-20 19:40:03+02	512	Test1	27729084232	Nevirapine	30	2	2	2
9	18	2005-10-20 19:35:44+02	512	Test2	27729084271	Nevirapine	30	2	2	2
22	17	2005-10-20 19:35:37+02	512	Test5	27729084244	Nevirapine	30	2	2	2
10	20	2005-10-20 19:39:37+02	720	Test2	27729084271	Nevirapine	45	2	2	2
12	6	2005-10-20 19:04:06+02	720	Test3	27729084514	Nevirapine	45	2	2	2
8	10	2005-10-20 19:11:02+02	818	Test2	27729084271	Nevirapine	22	2	2	2
21	8	2005-10-20 19:07:37+02	818	Test5	27729084244	Nevirapine	22	2	2	2
26	28	2005-10-21 14:43:24+02	818	Test5	27729084244	Nevirapine	22	2	2	2
1	5	2005-10-20 19:03:35+02	918	Test1	27729084232	Nelfinavir	10	2	2	2
29	7	2005-10-20 19:04:40+02	918	Test6	27729084500	Nelfinavir	10	2	2	2

Table B.4: Data collection errors from the database for the new adherence application - Part1/2

D2	D2 PC	D2 1d	D2 2d	D2 3d	D3	D3 PC	D3 1d	D3 2d	D3 3d
d4T	11	1	1	1	Combivir	27	2	2	2
d4T	11	1	1	1	Combivir	27	2	2	2
d4T	11	1	1	1	d4T	11	1	1	1
d4T	11	1	1	1	Combivir	27	2	2	2
d4T	11	1	1	1	Combivir	27	2	2	2
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
d4T	20	1	1	1	Combivir	52	4	4	4
AZT	12	3	3	3	Combivir	17	3	3	3
AZT	12	3	3	3	Combivir	17	3	3	3
AZT	12	3	3	3	Combivir	17	3	3	3
d4T	12	1	1	1	Combivir	17	4	4	4
d4T	12	1	1	1	Combivir	17	4	4	4
d4T	12	1	1	1	Combivir	17	4	4	4
d4T	12	1	1	1	Combivir	17	4	4	4
3TC	18	2	2	2	Abacavir	20	2	2	2
3TC	18	2	2	2	Abacavir	20	2	2	2
Saquinavir	16	3	3	3	ddl	36	1	1	1
Saquinavir	3	3	3	9	ddl	36	1	1	1
Saquinavir	16	3	3	3	ddl	1	1	1	1
d4T	24	1	1	1	Combivir	1	1	1	1
d4T	24	1	1	1	Combivir	32	1	1	1
d4T	17	1	1	1	Combivir	21	2	2	2
d4T	17	1	1	1	Combivir	21	2	2	2
d4T	17	1	1	1	Combivir	21	2	2	2
AZT	32	7	7	7	ddl	16	3	3	3
AZT	32	7	7	7	ddl	16	3	3	3

Table B.5: Data collection errors from the database for the new adherence application - Part2/2

Cellphone Menu Application Training Charts

A general usability evaluation questionnaire was used to assess the cellphone menu application training charts. Not only are the answers to the questionnaire important but also the general feedback noted during the testing process and this information is listed in Chapter 3 in the usability testing section.

USABILITY TESTING

Cellphone Training Charts											
User Information											
User No	3 digit #	105	107	109	115	113	104	111	114	Avg	
Age	years	30	32	23	26	27	22	25	23	26.0	
Gender	M/F	M	F	F	M	M	M	F	M		
Highest education											
(1.Primary, 2.High School, 3.Tertiary)	1/2/3	3	3	3	3	3	3	3	3	3.0	
Used a computer before	Y/N	Y	Y	Y	Y	Y	Y	Y	Y		
Level of cellphone experience	0 to 5	2	2	3	2	5	4	3	3	3.0	
English first language	Y/N	Y	N	N	Y	Y	Y	N	Y		
General Feedback Questionnaire											
Is there a logical flow in the chart?	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Avg	
Would menu screenshots help?	Y/N	Y	Y	Y	Y	Y	N	Y	N		
Did the chart help you learn the menu?	0 to 5	2	5	4	4	5	5	5	3	4.1	83%
Was the chart useful in menu navigation?	0 to 5	2	5	5	4	5	4	5	5	4.4	88%
How useful is the logical flow in navigation?	0 to 5	4	3	3	4	4	4	4	4	3.8	75%
How helpful are the chart overall?	0 to 5	4	4	3	4	3	3	4	4	3.6	73%
General Overall Score		60%	85%	75%	80%	85%	80%	90%	80%	79%	

Table B.6: Usability testing results summary of cellphone menu applications charts

B.3.2 Web Applications

In total three web applications were evaluated: Current, New and Offline Demonstration. The following three tables are the results from the usability tests and general system evaluation/comparisson questionnaire.

USABILITY TESTING

		Current (System C)									
User Information											
User No	3 digit #	106	107	108	109	111	116	117	118	119	Avg
Age	years	24	32	27	23	25	23	25	22	28	25.4
Gender	M/F	F	F	M	F	F	M	M	F	F	
Highest education											
(1.Primary, 2.High School, 3.Tertiary)	1/2/3	3	3	3	3	3	3	3	3	3	3.0
Used a computer before	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Level of cellphone experience	0 to 5	4	4	4	4	3	3	3	3	3	3.4
English first language	Y/N	N	N	Y	N	N	Y	Y	Y	Y	
Human Factors Testing (HST)											
Time to train/learn	minutes	1	2	2	2	1	2	2	1	2	1.7
Time to complete tasks	minutes	2	2	1	2	1	2	2	1	2	1.7
Are menus/displays consistent?	0 to 5	5	4	4	2	5	4	5	5	4	4.2
Are menus/displays simple?	0 to 5	5	4	5	3	5	4	4	5	4	4.3
Overall subjective satisfaction	0 to 5	5	4	4	3	5	4	5	5	4	4.3
HFT Score		100%	80%	87%	53%	100%	80%	93%	100%	80%	86%
System Usability Scale (SUS)											
Q1	score	5	4	4	4	5	4	4	5	4	
Q2	score	1	1	1	1	1	2	2	1	2	
Q3	score	5	4	5	5	5	4	5	4	5	
Q4	score	1	1	1	1	1	1	1	1	1	
Q5	score	5	4	4	5	5	5	5	4	5	
Q6	score	1	1	1	1	1	1	1	2	1	
Q7	score	5	5	5	4	4	5	5	5	5	
Q8	score	1	1	1	1	1	1	1	1	1	
Q9	score	5	5	5	5	5	5	5	5	5	
Q10	score	1	1	1	1	1	1	1	2	1	
SUS Score		100%	93%	95%	95%	98%	93%	95%	90%	95%	95%

Table B.7: Usability testing results summary of current, new and demo web applications - Part1/2

APPENDIX B. TESTING INFORMATION

Web Applications																			
New (System D)										Demo (System E)									
106	107	108	109	111	116	117	118	119	Avg	106	107	108	109	111	116	117	118	119	Avg
24	32	27	23	25	23	25	22	28	25.4	24	32	27	23	25	23	25	22	28	25.4
F	F	M	F	F	M	M	F	F		F	F	M	F	F	M	M	F	F	
3	3	3	3	3	3	3	3	3	3.0	3	3	3	3	3	3	3	3	3	3.0
Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	
4	4	4	4	3	3	3	3	3	3.4	4	4	4	4	3	3	3	3	3	3.4
N	N	Y	N	N	Y	Y	Y	Y		N	N	Y	N	N	Y	Y	Y	Y	
2	0	0	0	1	0	1	2	1	0.9	1	0	0	0	1	0	1	0	0	0.4
3	3	3	3	2	2	3	3	2	2.6	2	2	3	2	2	2	3	2	2	2.3
5	3	4	4	5	5	4	4	3	4.1	5	1	4	3	5	3	4	3	4	3.6
5	3	4	4	5	4	4	5	4	4.2	5	1	4	3	5	4	4	4	3	3.7
5	3	4	4	5	5	4	4	4	4.2	5	1	4	3	5	3	4	3	4	3.6
100%	60%	80%	80%	100%	93%	80%	87%	73%	84%	100%	20%	80%	60%	100%	67%	80%	67%	73%	72%
5	3	4	4	5	5	4	5	5		5	1	4	4	5	4	2	4	3	
1	1	1	1	1	1	1	1	1		1	5	1	1	1	2	4	2	1	
5	4	5	5	5	4	5	5	4		5	2	4	4	5	4	2	4	4	
1	5	1	1	1	1	1	1	1		1	3	1	1	1	3	3	1	2	
5	2	4	5	5	4	4	5	4		5	1	4	4	5	3	2	3	4	
1	4	1	1	1	2	1	1	2		1	5	1	1	1	1	4	1	1	
5	4	4	4	4	5	5	4	5		5	1	4	4	4	5	1	3	4	
1	2	1	1	1	1	1	1	1		1	1	1	1	1	1	3	3	1	
5	4	4	5	5	5	5	5	5		5	5	5	5	5	4	5	4	3	
1	1	1	1	1	2	2	1	2		1	4	1	1	1	2	3	2	1	
100%	60%	90%	95%	98%	90%	93%	98%	90%	90%	100%	30%	90%	90%	98%	78%	38%	73%	80%	75%

Table B.8: Usability testing results summary of current, new and demo web applications - Part2/2

General Feedback Questionnaire																			
Which Sys has the most functionality?	Y/N	D	D	C	D	E	D	D	C	D	Avg	6/9 correct = 67%							
Which Sys has the least functionality?	Y/N	C	E	E	E	C	E	E	E	E		7/9 correct = 78%							
How well does Sys E rep Sys D & E?	0 to 5	5	2	3	3	4	4	3	3	3	3.3	67% not bad rep							
Grade the level of functionality of Sys C?	0 to 5	5	3	3	5	4	5	5	4	2	4.0	80% C < D - correct							
Grade the level of functionality of Sys D?	0 to 5	5	4	4	5	3	5	4	5	4	4.3	87% D > C - correct							
Grade the level of functionality of Sys E?	0 to 5	5	1	1	2	5	1	2	3	2	2.4	49% lowest - correct							
Overall subjective satisfaction	0 to 5	5	4	4	4	5	4	4	5	4	4.3	87% fairly high							
General Overall Score		100%	56%	60%	76%	84%	76%	72%	80%	60%	74%								

Table B.9: Overall web application evaluation results

B.3.3 Sample Patient Home-visit Data

27 vars	Patient ID	###						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	select	##	##	##	##		
	Drug2	select	##	##	##	##		
	Drug3	select	##	##	##	##		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	v severe
3	Appointment							
	Month	##						
	Day	##						
	Time	select						
4	Alert	select						
5	Visit	Available	Unavailable					
27 vars	Patient ID	068						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nevirapine	22	5	5	5		
	Drug2	d4T	11	1	1	1		
	Drug3	combivir	27	2	2	2		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	v servere
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	-
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	-
3	Appointment							
	Month	3						
	Day	1						
	Time	12pm						
4	Alert	select						
5	Visit	Available	Unavailable					
27 vars	Patient ID	178						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nevirapine	12	2	2	2		
	Drug2	d4T	20	1	1	1		
	Drug3	combivir	52	4	4	4		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	v severe
3	Appointment							
	Month	11						
	Day	7						
	Time	10am						
4	Alert	-						
5	Visit	Available	Unavailable					

Table B.10: Sample patient home-visit data cards - Part1/4

APPENDIX B. TESTING INFORMATION

27 vars	Patient ID	223					
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?	
	Drug1	lopinavir	25	2	2	2	
	Drug2	AZT	12	3	3	3	
	Drug3	combivir	17	3	3	3	
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade moderate
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade mild
3	Appointment						
	Month	2					
	Day	12					
	Time	9am					
4	Alert	-					
5	Visit	Available	Unavailable				
27 vars	Patient ID	301					
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?	
	Drug1	nevirapine	25	1	1	1	
	Drug2	d4T	12	1	1	1	
	Drug3	combivir	17	4	4	4	
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade severe
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade mild
3	Appointment						
	Month	18					
	Day	10					
	Time	2pm					
4	Alert	select					
5	Visit	Available	Unavailable				
27 vars	Patient ID	445					
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?	
	Drug1	nefinavir	52	3	3	3	
	Drug2	3TC	18	2	2	2	
	Drug3	abacavir	20	2	2	2	
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade not gradable
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade severe
3	Appointment						
	Month	5					
	Day	1					
	Time	10am					
4	Alert	-					
5	Visit	Available	Unavailable				

Table B.11: Sample patient home-visit data cards - Part2/4

APPENDIX B. TESTING INFORMATION

27 vars	Patient ID	512						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nevirapine	30	2	2	2		
	Drug2	saquinavir	16	3	3	3		
	Drug3	ddl	36	1	1	1		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	v severe
3	Appointment							
	Month	2						
	Day	8						
	Time	8am						
4	Alert	-						
5	Visit	Available	Unavailable					
27 vars	Patient ID	681						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	effavirence	28	2	2	2		
	Drug2	ritonavir	20	2	2	2		
	Drug3	d4T	15	4	4	4		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	moderate
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	moderate
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	v servere
3	Appointment							
	Month	23						
	Day	8						
	Time	3pm						
4	Alert	-						
5	Visit	Available	Unavailable					
27 vars	Patient ID	720						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nevirapine	45	2	2	2		
	Drug2	d4T	24	1	1	1		
	Drug3	combivir	32	1	1	1		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	moderate
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	moderate
3	Appointment							
	Month	5						
	Day	12						
	Time	2pm						
4	Alert	-						
5	Visit	Available	Unavailable					

Table B.12: Sample patient home-visit data cards - Part3/4

APPENDIX B. TESTING INFORMATION

27 vars	Patient ID	818						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nevirapine	22	2	2	2		
	Drug2	d4T	17	1	1	1		
	Drug3	combivir	21	2	2	2		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	severe
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	severe
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
3	Appointment							
	Month	6						
	Day	6						
	Time	1pm						
4	Alert	-						
5	Visit	Available	Unavailable					
27 vars	Patient ID	918						
1	Drug	Drug Name	Pills left?	Doses 1?	Doses 2?	Doses 3?		
	Drug1	nefinavir	10	2	2	2		
	Drug2	AZT	32	7	7	7		
	Drug3	ddl	16	3	3	3		
2	Symptom	Option1	Option2	Option3	Option4	Option5	Symp Grade	
	Symptom1	Abd pain	Vomitting	Rash	Fever	Other	Grade	mild
	Symptom2	Abd pain	Vomitting	Rash	Fever	Other	Grade	-
	Symptom3	Abd pain	Vomitting	Rash	Fever	Other	Grade	-
3	Appointment							
	Month	22						
	Day	2						
	Time	11am						
4	Alert	-						
5	Visit	Available	Unavailable					

Table B.13: Sample patient home-visit data cards - Part4/4

B.4 Performance Testing

B.4.1 Web Applications Response Times

Web Application Tests (Response Time (ms)) - outside LAN								
simultaneous HTTP requests to https://xxx.xxx.uct.ac.za/login.php.in								
	10 calls	20 calls	50 calls		100 call			
	1-10	1-20	1-25	26-50	1-25	26-50	51-75	76-100
1	2724	1211	2404	6630	7230	10645	13349	15282
2	2804	1281	2444	6690	7250	10846	13549	15402
3	2864	1361	2464	6820	7280	10946	13449	15612
4	2954	1432	2624	6860	7290	11466	13470	15612
5	3014	1512	2714	6940	7320	11347	13500	15512
6	3094	1582	2744	7010	7340	11407	13860	15702
7	3174	1642	2804	7070	7350	11457	13900	15633
8	3274	1732	2884	7150	7971	11457	13830	15903
9	3355	1822	2954	7321	8202	11477	14000	15973
10	3565	2814	3025	7902	8332	11777	14070	16033
11		2884	3105	7431	8462	12077	14140	15913
12		2954	4066	8112	8572	12137	14130	16023
13		4276	4447	8112	8642	12177	14240	16063
14		4326	5108	8863	8732	12408	14331	16283
15		4406	5188	9434	9313	12668	14381	16183
16		4466	5318	9474	9383	12828	14651	16403
17		4536	5338	9544	9484	12918	14641	16384
18		4616	5949	10135	9554	12878	14721	16454
19		4707	6009	10205	9684	12829	14911	16464
20		5367	6099	10255	9844	13099	14862	16514
21			6209	10315	9884	13179	14872	16644
22			6239	10395	9904	13199	15002	17525
23			6379	10675	10295	13169	15082	18977
24			6479	11026	10375	13269	15262	23564
25			6550	11166	10585	13479	15312	23945

Table B.14: Simultaneous HTTP request response times from outside the LAN

Web Application Tests (Response Time (ms)) - outside LAN								
simultaneous HTTP requests to https://xxx.xxx.uct.ac.za/login.php.in								
	10 calls	20 calls	50 calls		100 call			
	1-10	1-20	1-25	26-50	1-25	26-50	51-75	76-100
1	2724	1211	2404	6630	7230	10645	13349	15282
2	2804	1281	2444	6690	7250	10846	13549	15402
3	2864	1361	2464	6820	7280	10946	13449	15612
4	2954	1432	2624	6860	7290	11466	13470	15612
5	3014	1512	2714	6940	7320	11347	13500	15512
6	3094	1582	2744	7010	7340	11407	13860	15702
7	3174	1642	2804	7070	7350	11457	13900	15633
8	3274	1732	2884	7150	7971	11457	13830	15903
9	3355	1822	2954	7321	8202	11477	14000	15973
10	3565	2814	3025	7902	8332	11777	14070	16033
11		2884	3105	7431	8462	12077	14140	15913
12		2954	4066	8112	8572	12137	14130	16023
13		4276	4447	8112	8642	12177	14240	16063
14		4326	5108	8863	8732	12408	14331	16283
15		4406	5188	9434	9313	12668	14381	16183
16		4466	5318	9474	9383	12828	14651	16403
17		4536	5338	9544	9484	12918	14641	16384
18		4616	5949	10135	9554	12878	14721	16454
19		4707	6009	10205	9684	12829	14911	16464
20		5367	6099	10255	9844	13099	14862	16514
21			6209	10315	9884	13179	14872	16644
22			6239	10395	9904	13199	15002	17525
23			6379	10675	10295	13169	15082	18977
24			6479	11026	10375	13269	15262	23564
25			6550	11166	10585	13479	15312	23945

Table B.15: Simultaneous HTTP request response times from inside the LAN

B.4.2 Incoming SMS Transfer Times

1 SMS x 6 times (one by one)				1 SMS x 6 times (at once)				1 SMS x 12 times (at once)				1 SMS x 18 times (at once)					
			transfer time (s)				transfer time (s)									transfer time (s)	queue delay (s)
	send	receive		send	receive			send	receive		send	receive		send	receive		
1	13:48:54	13:49:05	11	13:59:51	14:00:01	10	0	14:02:53	14:03:02	9	0	0	14:05:10	14:05:20	10	0	0
2	13:50:25	13:50:35	10	13:59:51	14:00:06	15	5	14:02:53	14:03:08	15	6	6	14:05:10	14:05:25	15	5	5
3	13:51:41	13:51:53	12	13:59:51	14:00:12	21	6	14:02:53	14:03:18	25	10	10	14:05:10	14:05:31	21	6	6
4	13:52:45	13:52:57	12	13:59:51	14:00:18	27	6	14:02:53	14:03:24	31	6	6	14:05:10	14:05:37	27	6	6
5	13:53:48	13:53:59	11	13:59:51	14:00:23	32	5	14:02:53	14:03:30	37	6	6	14:05:10	14:05:41	31	4	4
6	13:54:37	13:54:47	10	13:59:51	14:00:31	40	8	14:02:53	14:03:34	41	4	4	14:05:10	14:05:49	39	8	8
7								14:02:53	14:03:40	47	6	6	14:05:10	14:05:55	45	6	6
8								14:02:53	14:03:46	53	6	6	14:05:10	14:05:59	49	4	4
9								14:02:53	14:03:52	59	6	6	14:05:10	14:06:05	55	6	6
10								14:02:53	14:03:58	65	6	6	14:05:10	14:06:11	61	6	6
11								14:02:53	14:04:04	71	6	6	14:05:10	14:06:17	67	6	6
12								14:02:53	14:04:09	76	5	5	14:05:10	14:06:23	73	6	6
13													14:05:10	14:06:29	79	6	6
14													14:05:10	14:06:34	84	5	5
15													14:05:10	14:06:40	90	6	6
16													14:05:10	14:06:48	98	8	8
17													14:05:10	14:06:56	106	8	8
18													14:05:10	14:06:02	112	6	6

Table B.16: Table of transfer times of SMSs from cellphone handsets to the database via GSM modem

Appendix C

Photographs

C.1 Cellphone

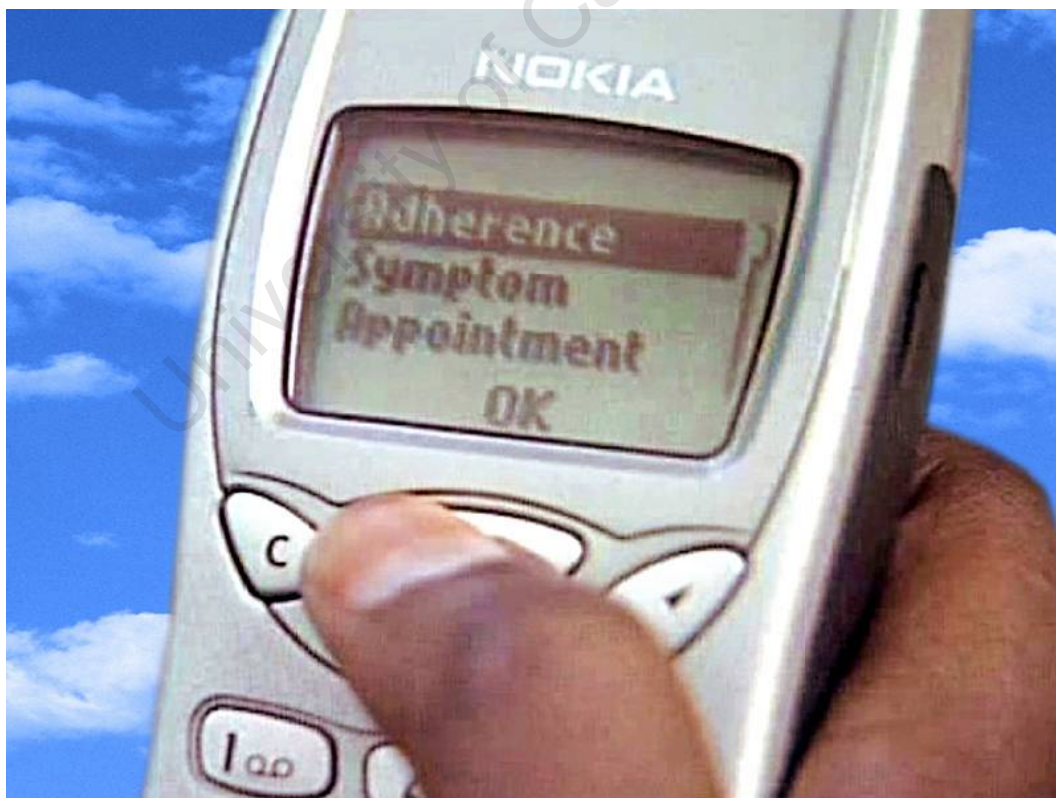


Figure C.1: WIG menu application on a cellphone

C.2 Home-based Carer Training



Figure C.2: Home-based carer training at the Gugulethu Clinic pilot site



Figure C.3: Home-based carer training at the Gugulethu Clinic pilot site

C.3 GSM Modem



Figure C.4: The GSM modem



Figure C.5: The GSM modem

C.4 Server Room



Figure C.6: The server room - network switch



Figure C.7: The server room - Cell-Life servers

Appendix D

Additional Information

D.1 Cellphone Menu Training Charts

The WIG cellphone menu training charts of the *Original Menu* and the *Adherence Menu* can be found in Figures 3.3 and 3.4. The *Monitor Menu* and *Social Menu* are as follows:

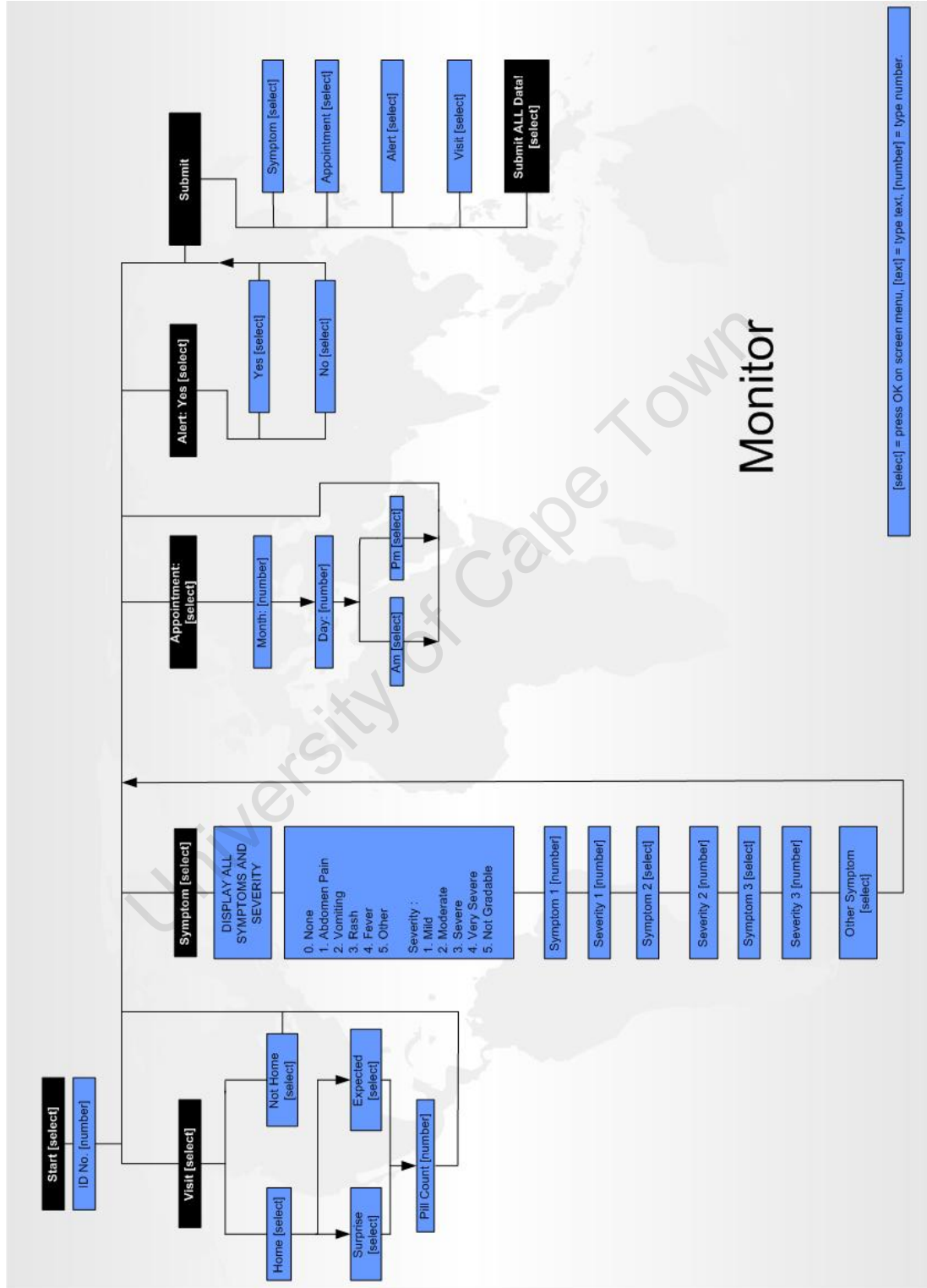


Figure D.1: *Monitor Menu* Training Chart

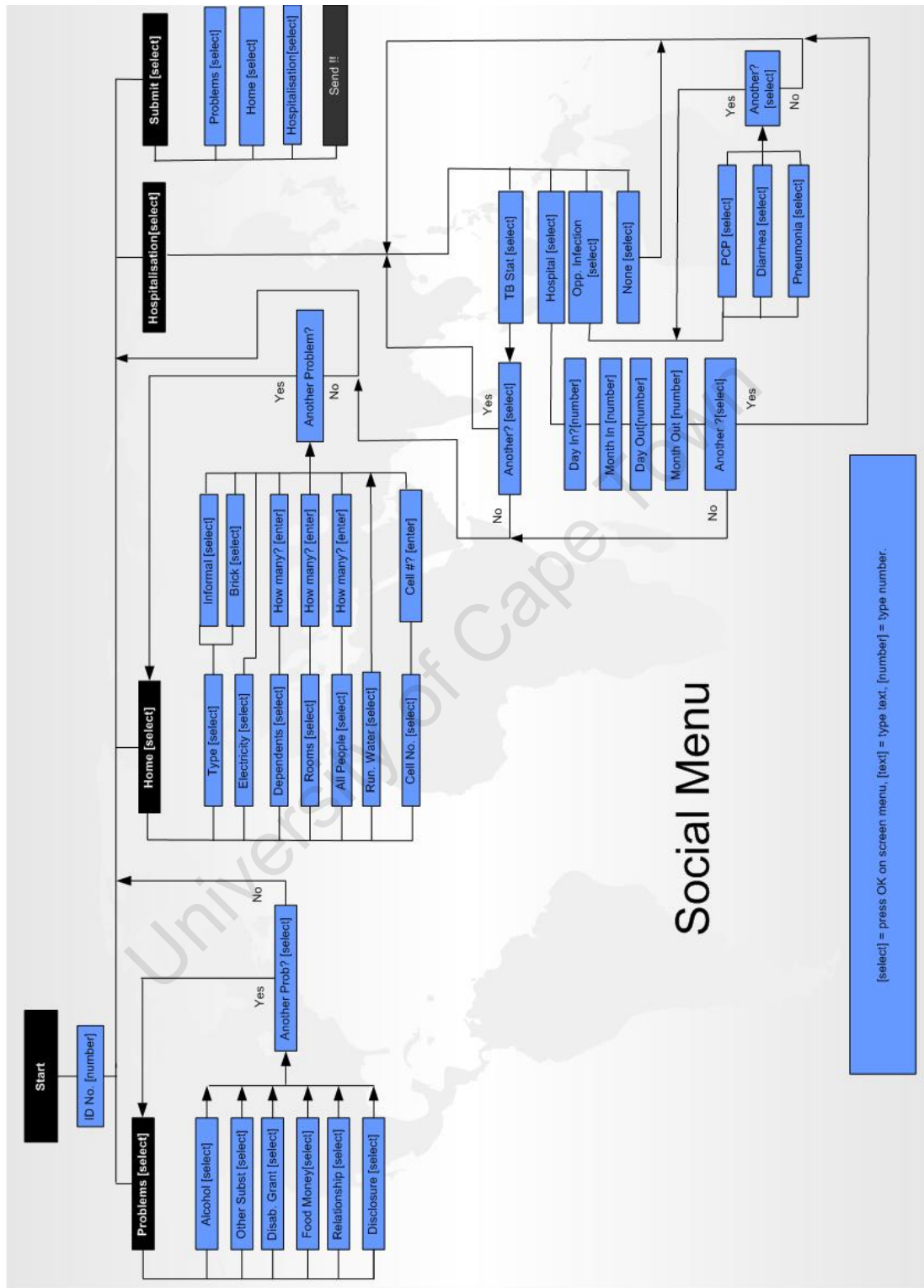


Figure D.2: *Social Menu* Training Chart

D.2 Offline Website Demonstration

These are sample screen shots from the Cell-Life website (www.cell-life.org):

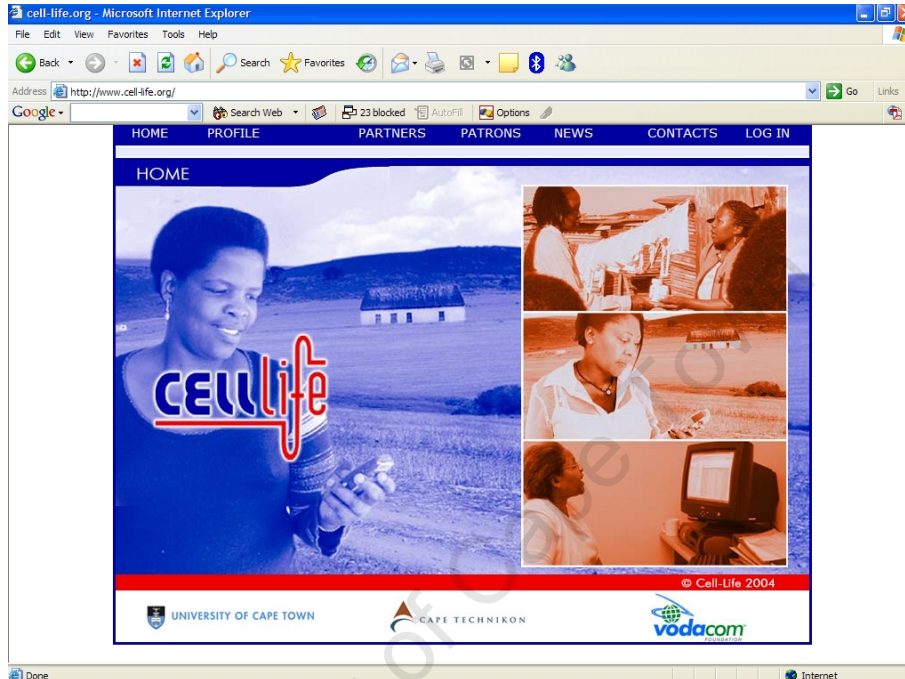


Figure D.3: Cell-Life Website - Home Page

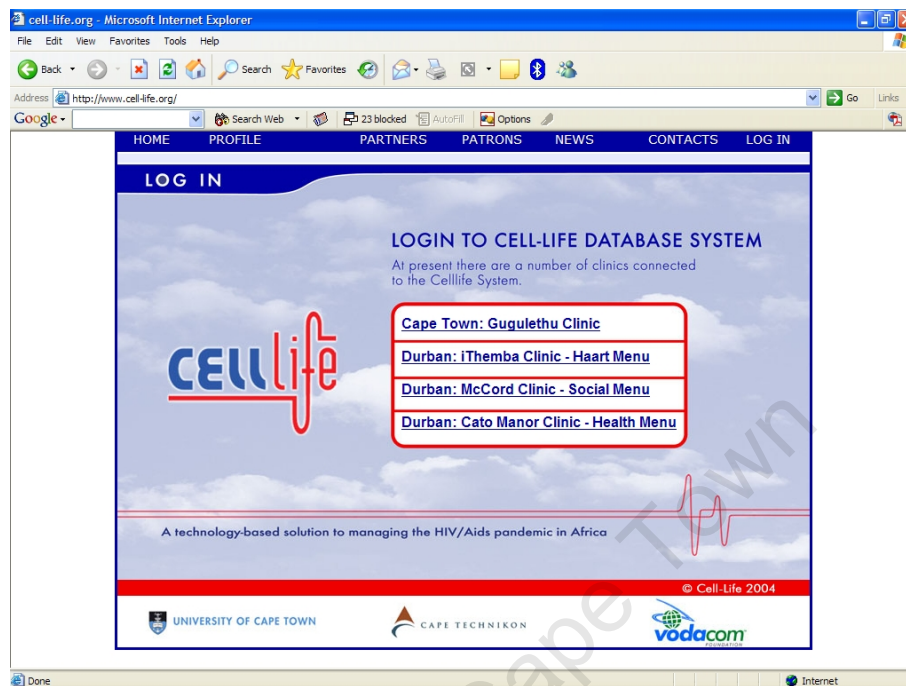


Figure D.4: Cell-Life Website - Login Page

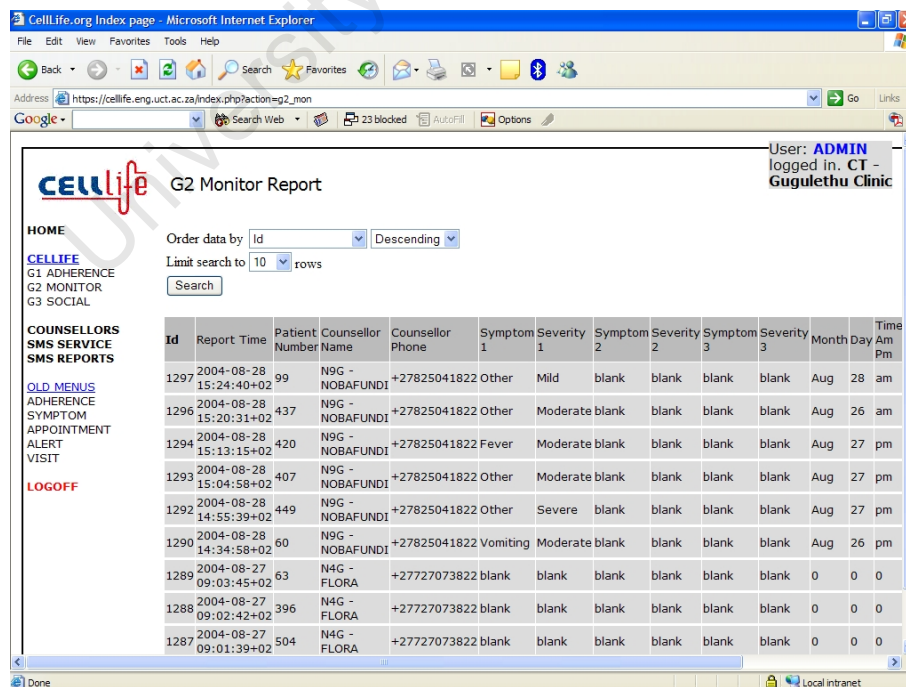


Figure D.5: Cell-Life Website - Pilot Site Login

APPENDIX D. ADDITIONAL INFORMATION

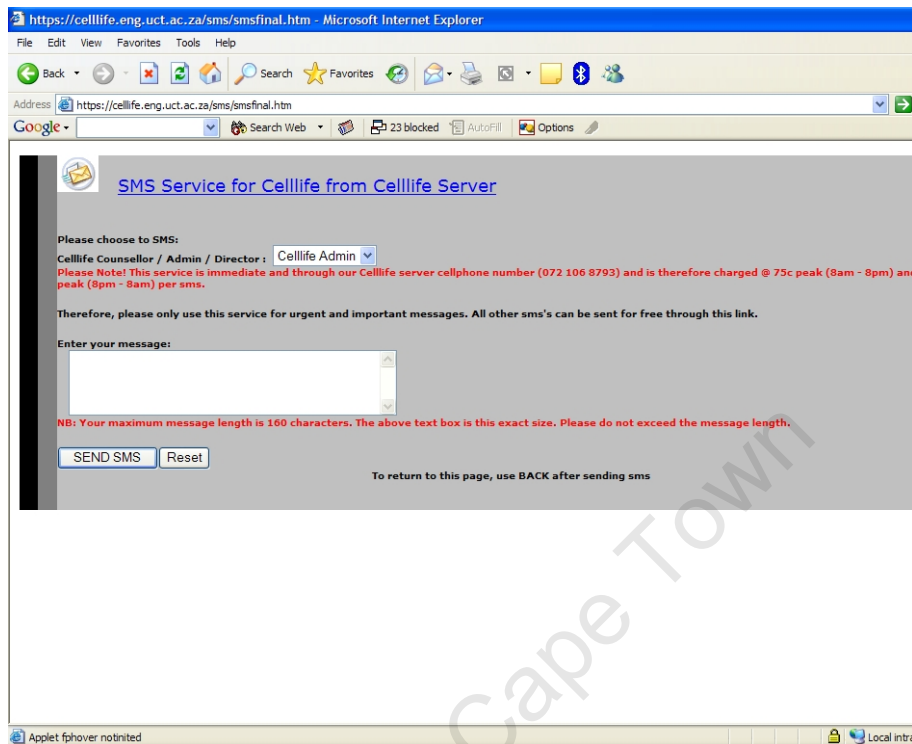


Figure D.6: Cell-Life Website - Outward SMS *smsfinal.htm*

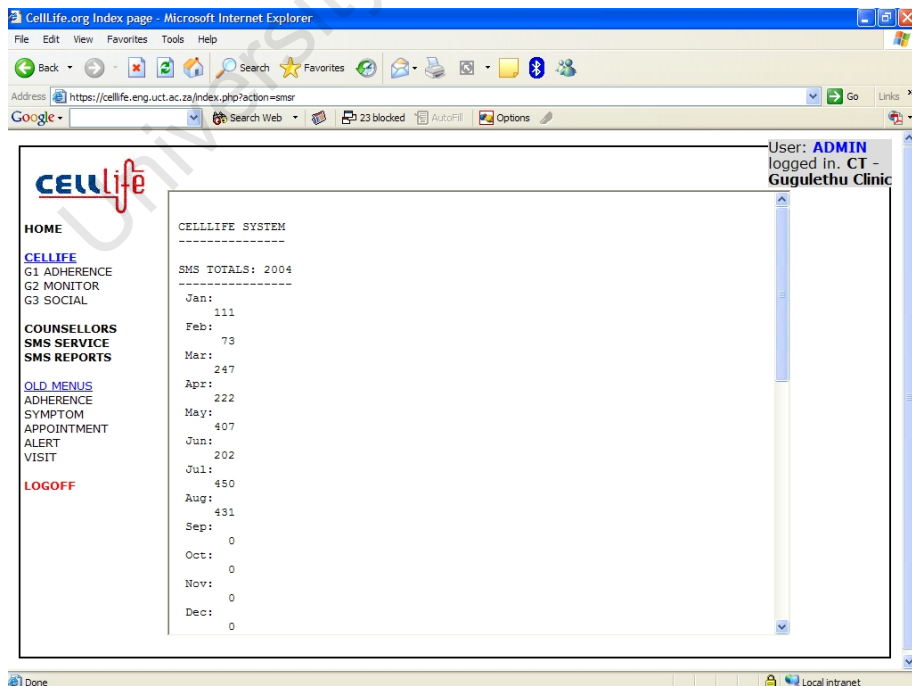


Figure D.7: Cell-Life Website - SMS Report Totals

Appendix E

CDRom

E.1 CD Insert

The CD Insert contains:

1. Thesis document (PDF Format)
2. Samples of Programming Code
3. Offline Web Site Demonstration (Old Web Site)